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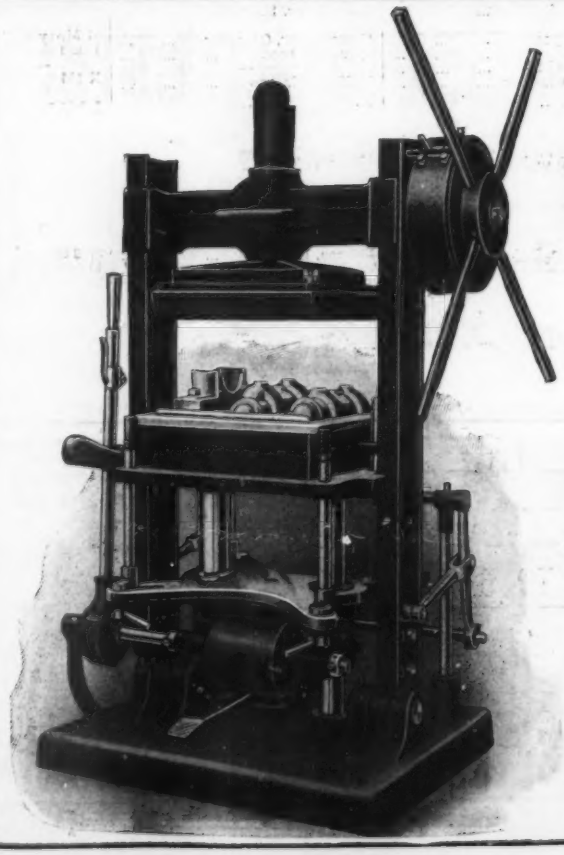

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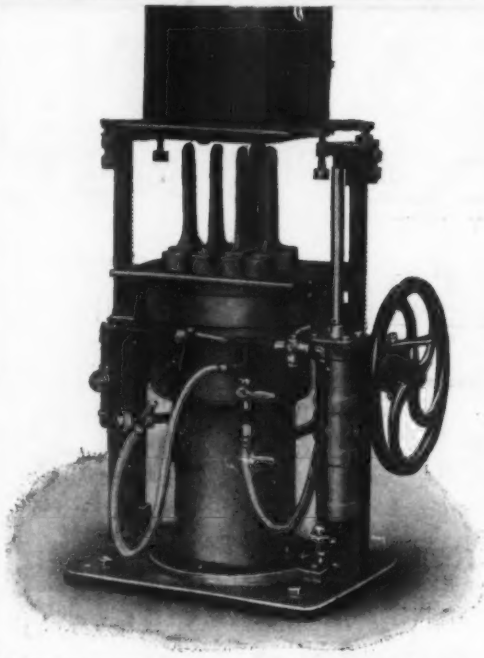

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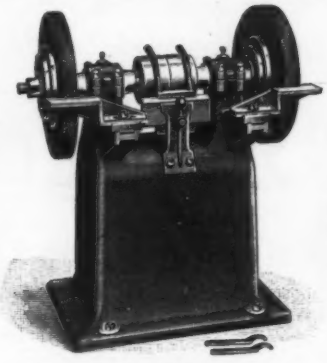

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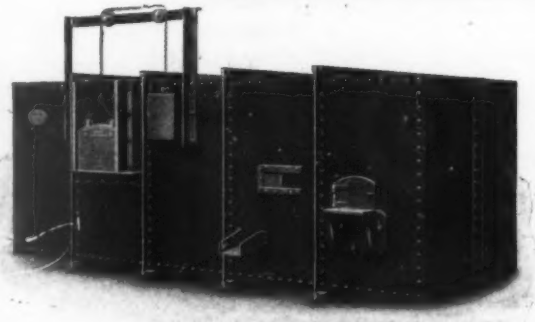

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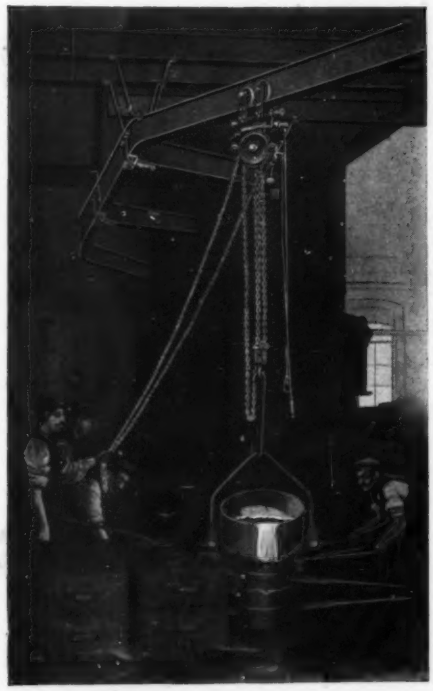

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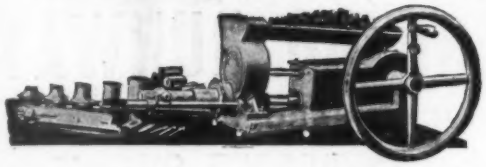

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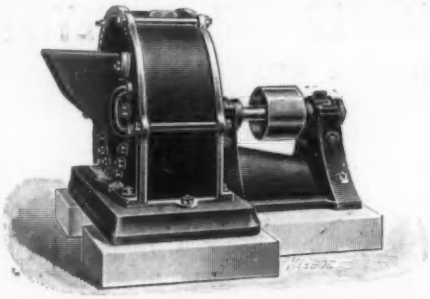

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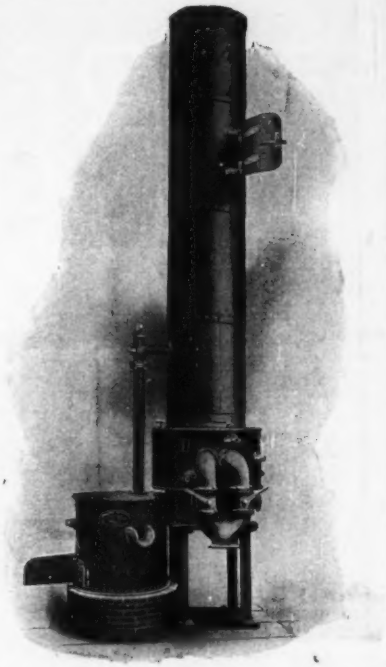

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Contents.

	PAGE
Notes and Comments	11
Manganese in Cast Iron and the Volume Changes During Cooling	13
A New Electric Furnace for Steel Melting and Refining	21
Castings as Igneous Rocks	22
Patterns for Gear Wheels	23
Slow Melting for Aluminium	27
The Inspection of Castings	28
Working an Oxyacetylene Blowpipe	29
Some Foundry Difficulties	30
Index to Volume 12, 1910	i. to iv.
The Production of Castings to withstand High Pressures	34
Electric Power Required to Melt Metals	40
The Influence of Briquetted Turnings on Cupola Iron	41
A Discussion on Blowers	42
Recovering Metal and Charcoal from Crucible Skimmings	44
Foundry Plant and Equipment	45
A Foundry Grab Bucket	46
A Pneumatic Respirator for the Cleaning Room	46
Hydraulic Pig-Iron Breaker	47
A Home-Made Sand-Blast	47
Inventions	48
New Companies	49
Trade Talk	49
Deaths	52
Personal	54
Prices of Metals	54

Forthcoming Events.

JANUARY 14.

British Foundrymen's Association (Lancashire Branch).—Open meeting for discussion on Foundry Problems, and annual dinner.

British Foundrymen's Association (Scottish Branch).—Monthly Meeting.

JANUARY 17.

British Foundrymen's Association (Sheffield Branch).—"Cupola Practice," by R. Mason.

JANUARY 23.

British Foundrymen's Association (Birmingham Branch).—"Manganese in Cast Iron," by H. I. Coe, M.Sc., Birmingham.

FEBRUARY 4.

British Foundrymens Association (Lancashire Branch).—"The Application of the Microscope to Foundry Practice," by G. Hailstone, Birmingham.

NOTES AND COMMENTS.

Review of the Past Year.

At the commencement of a new year it may not be out of place to briefly review the general business aspect which has been presented by the iron and steel trades during the past 12 months, for the prosperity of the foundry trades is closely associated with that of the other branches of the iron and steel industry. The year 1910 must be described as only a moderately prosperous time for those engaged in the iron and steel trades, more especially as regards the pig-iron branches. The general trade of the United Kingdom improved materially during the year, there being sufficient evidence of that in the Board of Trade returns of our exports and imports, but it cannot be said that the iron trade shared in the revival to the same extent as other industries, though there is no getting away from the fact that business on the whole was more satisfactory, not only in extent, but also in value, than in either 1908 and 1909. Especially in the Cleveland pig-iron trade did the year fall short of expectations. When January opened traders were counting upon the renewal of the demand from the United States for Cleveland pig-iron. That was the chief factor in bringing about the rise in the price of Cleveland warrants to 52s. 4½d. cash buyers, which was recorded on January 24, though that figure proved to be the maximum of the year, for the demand from the States did not materialise as anticipated. Not since January has so high a figure as 52s. been reported for Cleveland warrants. The most prominent feature of the Cleveland pig-iron trade in 1910 was that which had to be recorded in 1909—the pig-iron makers produced too much Cleveland pig-iron, and as a consequence the stock in Connal's public store was increased over 130,000 tons, while in 1909 the increase had been 253,000 tons. If the production in 1910 had been 8 per cent. less, it would have sufficed to satisfy requirements.

In the South Staffordshire centres a somewhat disappointing year was experienced, though latterly there was a tendency to rally, and the last month of the year showed a decidedly firmer tone. In West Cumberland the hematite pig-iron trade showed an improvement upon the previous year, despite the continued high prices of raw materials. The steel trade, however, was unsatisfactory, and the demand restricted. The industry in South Wales showed considerable vitality, and in Scotland also, there was evinced a decided improvement as compared with the year 1909. The market fluctuations of pig-iron prices were within comparatively narrow limits, and steel prices rose by 15s. during the year. The iron and steel trades of South Yorkshire in some respects presented a much more satisfactory condition of things than in the previous year. Employment was better, but the most noteworthy revival occurred in the armament lines and in the lighter trades, the former due to the enlarged naval programme and the latter being chiefly the result of an increased export trade. On the other hand, there was little real improvement in heavy engineering, and apart from specialities

it is improbable that manufacturers have had any considerable orders on their books. The cost of raw materials was greater than in 1909, pig-iron ruling at a higher average, and coal being from 6d. to 9d. per ton up. One of the features of the Sheffield district crucible steel trade in high-class steels was the growing preference for the best qualities for the wearing parts of machinery, the cheaper and inferior qualities being at a discount. The export trade underwent a sharp recovery, but apart from the automobile industry, which used increased quantities, the home trade did not expand to any great extent owing to the small requirements of general engineering. As the Board of Trade returns showed, the exports of cutlery and plated goods rose substantially. The season's trade was a remarkably busy one. Makers of edge tools, too, did much better than in the previous year. In addition to purely armament material the large firms in the Sheffield district have also been in receipt of satisfactory orders for large castings and forgings for shipbuilding and marine work. The revival in shipbuilding brought a good deal of work to Sheffield, but the lock-out during the past quarter resulted in a curtailment of orders and the suspension of deliveries. Moulders' wages were raised by 2½ per cent. in the early autumn, thus regaining part of the reduction made in the preceding slump.

On the whole, the year 1910 was not a boom period by any means, but there was a decided recovery from the depression of the previous two years, and with the termination of the labour disputes that have so unsettled trade at some periods of the year, the prospects for the present year may be considered fairly bright.

High Pressure Aluminium Bronze Castings.

The investigations by Professor Carpenter and Mr. C. A. Edwards, which we detail on another page, reveal a great field of possibilities for certain of the aluminium bronzes. The application of these alloys was to some extent indicated in previous researches undertaken for the Alloys Research Committee; but the present experiments, which deal to a great extent with practical foundry procedure and its effect on quality, bring the alloys nearer to the foundryman, for they touch the very points on which practical success rests. The difference between results obtained under laboratory conditions and those obtained in foundry practice have been remarked on many times, for it is common knowledge that experimental results are frequently not maintained in practice. The conditions have been worked out under which hydraulic castings of copper-aluminium bronzes (containing from 9 to 11 per cent. of aluminium, according to the size and shape of the casting), can be produced, which will be capable of withstanding pressures ranging from 14 to 20 tons. It has been shown, also, that 9 to 10 per cent. of aluminium gives the most suitable composition of the alloy, higher percentages being successful only when employed for small castings. It may not be out of place to summarise the precautions which were found essential to the production of castings capable of holding the high pressures aimed at. These precautions are as follows:—The alloy must be poured very slowly. It should be cast at a temperature of not more than 50 degrees C to 80 degrees C. above that at which freezing begins. The gate should be so arranged that the metal enters the mould at the lowest possible point. Broadly speaking, almost any form of gate will do, but it has been found advantageous to provide a sort of well at the bottom and to use rather a narrow opening. In the case of green-sand moulds, care must be taken that the sand is not too damp, particularly in the lower parts where the metal rests on it. If a rather close sand is used it is far safer to dry the surface of the lower part of the mould. In large castings the use of risers is essential to overcome the shrinkage of the alloy.

If these conditions are observed, after sufficient practice, castings can be regularly made that are absolutely free from dross and nearly always sound. The information contained in the Paper, we think, should prove most acceptable and useful to all brass and bronze founders who produce high-pressure castings such as hydraulic valves.

Discussion on Foundry Difficulties.

At the last meeting of the Birmingham Branch of the British Foundrymen's Association (see page 30), a commendable feature was introduced. Members had previously been invited to send in particulars of any difficulties they had encountered in the course of their work, and these problems formed the subjects of the evening's discussion. As a result, a very useful and practical meeting was held, at which various members were materially assisted in their work. This procedure might with advantage be followed more frequently, for whatever the claims of scientific discourses may be (and we do not dispute their importance), the value of such practical discussions as the one above mentioned cannot be doubted for one moment. It is just that sort of thing that the foundryman requires to help him from day to day. One is in danger of overlooking the fact that in a representative gathering of foundrymen there are two practically distinct classes, the technically well educated man, who has probably a good knowledge of the science of metallurgy, and the man whose education at his calling has been gained by intimate contact with everyday practice, and often discouraging failure and futile experiment. There are many points in the behaviour of metals under foundry treatment that to the former present no great problems, but which to the latter are often inexplicable; and this results not from any essential differences in the intelligences of the two, but from the fact that the training and education of the one has been on different lines to that of the other. To the first such a record of investigation as that on "Manganese in Cast Iron and the Volume Changes during Cooling," which we publish on another page, may be pregnant with important information; to the latter it may be only a dimly understood treatise outside the operations of the foundry. It will be readily understood then, that when the topic under discussion is directly and obviously related to the every-day features of foundry work, the average foundryman is on ground with which he is familiar, and which he can thoroughly understand and appreciate. One of the main objects of the British Foundrymen's Association is the assistance of the worker in his difficulties, and we can only express commendation when those whose experience and education have given them some advantage in the solution of problems, apply their knowledge to the solution of their fellow-workers' difficulties. Such practical fraternising should go a long way to increase the membership of the Association.

At a meeting of the Scottish Branch of the British Foundrymen's Association, held at the Technical College in Glasgow during December last, the chair was taken by Professor Campion of the Metallurgical Department of the Technical College, and about 300 members were present. A Paper was read by Mr. J. F. P. Lewis entitled "Improved Cast Iron—How to get it in the Foundry." The Paper was accompanied by records of a series of tests of tensile strength and specific weight of various qualities of cast iron, some very high results being reached. The lecture, which provoked a great deal of interest, will be dealt with in our next issue, as considerations of space prevent its publication in the current number.

Manganese in Cast Iron and the Volume Changes During Cooling.

By H. I. Coe, M.Sc. (Birmingham).

It has long been known that certain fluids expand while passing from the liquid to the solid state, this phenomenon being, without doubt, first observed in the case of water which, on freezing to ice, expands with the consequence that the ice rises and floats on the surface of the remaining liquid. Réaumur appears to have been the first to state that certain metals—such as cast iron, bismuth, and antimony—expand on solidification, although this statement was challenged by R. Mallet,* who, in spite of experimental evidence, attempted to prove that cast iron did not expand on solidification. It was left to Wrightson† to prove conclusively by means of the "tektometer" and the "oncosimeter," that a Cleveland foundry iron possessed less density in the solid state near the temperature of liquefaction than in the liquid state; in other words, that there must be an expansion of the iron while passing from the liquid to the solid state. Experiments were performed by various investigators, notably Roberts-Austen, which, however, gave information as to the nature of the metals while still in the liquid condition, rather than at or after solidification; and it was Keep‡ who first evolved an apparatus which recorded volume changes from the commencement of solidification down to the ordinary temperature. The chief drawback of the experiments described in his Paper was the absence of any temperature determinations, and it was not until 1906 that a simple apparatus correlating both volume and temperature changes was devised, and described by Professor Turner.§ Some remarkable types of curves for different cast irons were reproduced in his Paper, which indicated how intimately internal changes in the constitution were associated with the volume changes, and this connection was amply illustrated later in the case of the brasses.

What was probably the first systematic research on volume changes was that described by Professor Turner and Mr. M. T. Murray¶ in a Paper to the Institute of Metals. The relation brought out between the curves of expansions during the solidification of the brasses and the accepted equilibrium diagram was very remarkable, and it was to investigate further this relationship of expansion to ordinary microscopic and pyrometric data that the author, under the guidance of Professor Turner, pursued the following research on the influence of manganese on the volume changes during the cooling of cast iron.

Before proceeding to the description of the research it would be well to make a general note on volume changes during solidification. It has been urged that the instrument used does not give a measure of volume changes but rather of linear changes only, and it has been suggested that the effect measured is a mechanical thrust due to the growth of the crystals in the outer shell first formed during solidification. This suggestion does not appear to hold in the case of the white irons with varying manganese content; the general structure, showing arborescent primary crystals, is identical in nearly all the bars, although the expansion on solidification varies from zero through a maximum to zero several times in passing through the series.

The author's research was divided into two sections, the first of which dealt with the effect of manganese on white iron, and the second with the effect on grey iron.

I. THE EFFECT OF MANGANESE ON THE VOLUME CHANGES OF WHITE IRON.

The effect of manganese on white iron was first studied, owing to the greater simplicity of the inquiry, there being but two variables, iron and manganese From a practical point of view, the second section is perhaps the more important.

Materials Used.

(A) *American Washed White Iron.*—This material, which was used as the base of the series, was hard and crystalline, and contained a large number of oxidised blow-holes; about a hundredweight was sampled and analysed, giving the following composition:—Combined carbon 3.05 per cent., graphitic carbon, nil manganese 0.035 per cent., silicon 0.010 per cent., phosphorus 0.008 per cent., sulphur 0.007 per cent.

(B) *Manganese Iron-carbon Alloy.*—Since it was desired to keep the carbon approximately constant throughout the series, it was endeavoured to produce an alloy rich in manganese and containing about 3 per cent. of carbon with the least possible quantity of impurities. This was done by melting about 15 lbs. of a high-grade ferro-manganese (kindly supplied by the Darwen and Mostyn Iron Company), with somewhat more than its weight of pure very mild steel; a raw clay pot (previously annealed) was used, the melted metal being cast into iron ingot moulds in slabs weighing about 4 lbs. each. There was a loss of 10 ozs. of metal in the slag and by volatilisation: the ingots, which broke readily, and showed a columnar spiegel-like fracture, were sampled, and analysed with the following results:—Combined carbon 3.80 per cent., graphitic carbon nil, manganese 40.20 per cent., silicon 0.140 per cent., phosphorus 0.104 per cent., sulphur 0.005 per cent.

Apparatus Used.

This was similar to that described by Professor Turner in his original Paper on volume changes, and consisted of a mould and extensometer: the only alteration made was in the size of the pattern, which was ¾-in. square, as compared with ½-in. in the early experiments, thus increasing the volume of the casting in the ratio of nine to four, and so affording a better record of temperature changes than the smaller bar. A glance at Fig. 1 will show the general arrangement; the metal poured through the gate D first solidifies around the fixed vertical pin A and the movable horizontal pin B, and thus linear changes in the length AB are registered at 35-fold magnification on the scale of the extensometer. The ordinary platinum

* "Proceedings of the Royal Society," 1873, vol. xxii., p. 366, 1874, vol. xxiii., p. 209.

† "On some Physical Changes Occurring in Iron and Steel at High Temperatures." "Journal of the Iron and Steel Institute," 1879, vol. ii., p. 418: 1880, vol. i., p. 11.

‡ "Cooling Curves and Tests for Cast Iron." Keep, "Cast Iron," p. 50; also "Journal of the Iron and Steel Institute," 1895, No. II., p. 227.

§ "Volume and Temperature Changes during the Cooling of Cast Iron," "Journal of the Iron and Steel Institute," 1906, No. I., pp. 48-74. (See IRON AND COAL TRADES REVIEW, May 11th, 1906, page 1623.)

¶ "The Copper-Zinc Alloys: A Study of Volume Changes," "Journal of the Institute of Metals," 1909, No. II., pp. 98-150.

platinum-rhodium thermo-couple is inserted at C, the actual junction being left bare, so that definite arrests might be obtained on the cooling curve, in spite of the rapid chilling of the metal.

The pyrometer was frequently calibrated against lead aluminium, silver-copper or silver, and copper; readings were taken in all cases from a millimetre

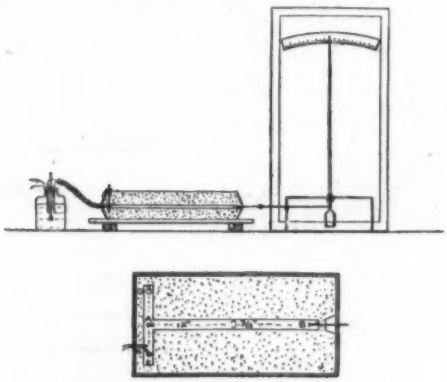

FIG. 1.—MOULD AND EXTENSOMETER, AND PLAN OF MOULD.

scale on to which a beam of light was reflected from a mirror-galvanometer of the D'Arsonval type.

Casting a Bar.

The amount of metal required to fill the mould averaged, in the case of the white irons, about 54 ozs., and this weight of white iron and alloy to produce the required percentage of manganese was accordingly put in a flue-dried and annealed clay pot, which was then placed in a coke-fired crucible furnace of the "well" type; prior to pouring, the metal was thoroughly stirred with an iron rod.

While the metal was melting (and this took about fifty minutes) the mould and extensometer were being got ready, and a clock connected with an electric bell was started; by this means ten-second, or if desired five-second, readings could be taken simultaneously on both pyrometer and extensometer scales. Three persons were required for the conduct of an experiment; one to read the pyrometer scale, another to attend to the extensometer, and the third to pour the metal into the mould, and as soon as the gate was full, to give the signal to start taking observations. Five-second readings were taken until the metal had completely solidified, after which readings were continued every ten seconds; it will be seen that two curves can be plotted, so that taking time along the abscissæ, pyrometer and extensometer records, at

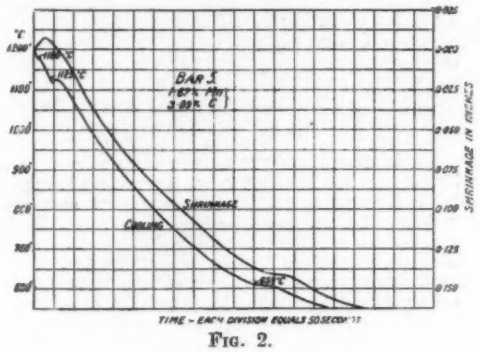

FIG. 2.

any moment, may be compared. With each bar about a hundred readings were taken, the temperature having then fallen to near 400 degrees C.; time did not permit of readings being taken down to the temperature of the room.

A series of mixtures was made, the manganese content of which ranged from 0 to 40 per cent.; in each case an excess of 5 per cent. of the manganese content required being added. Analyses showed, however, that the amount of manganese lost varied considerably, the chief sources of loss being by volatilisation and slagging of oxide formed.

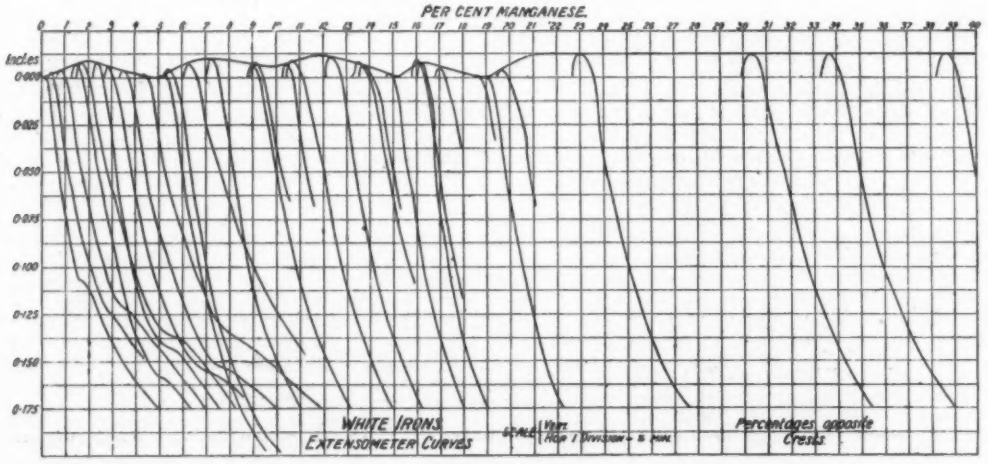

FIG. 1A.

With the high-percentage manganese alloys it was interesting to watch the brown fume of volatilising manganese (probably oxidised immediately) which curled up from the surface of the fluid metal in the pot. Attention is drawn to this point, since Mr. Wraight,* in a Paper to the Iron and Steel Institute on "The Preparation of Carbon-free Ferro-man-

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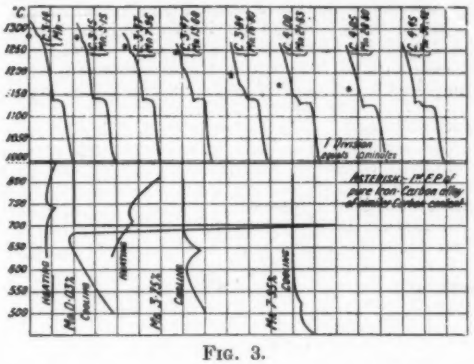

FIG. 3.

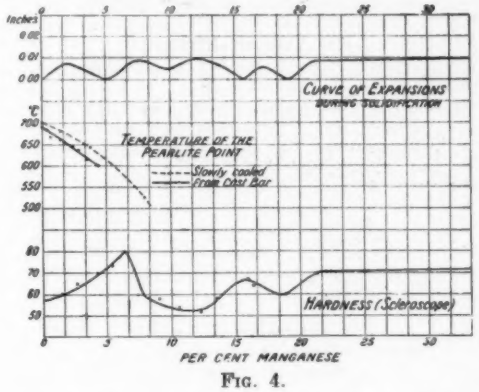
Curve of Expansions during solidification
Temperature of the Pearlite Point
Slowly cooled from cast bar
Hardness (Scleroscope)
Per cent Manganese

FIG. 4.

cooling in the crucible. The former manifest a great deal of commotion, and certain reactions which go on appear to be accompanied by an evolution of heat; the latter, on the contrary, cool and solidify quite normally.

The compositions of the cast bars are given in Table I., together with their expansions during solidification. The appearance of the gate with over 20 per cent. manganese indicates that the surface chilled rapidly, whilst the interior was still fluid; therefore when the gate "piped," the metal surface was unable to follow the movement of the metal underneath, so leaving a cavity in which crystals formed. The surface of bars above 10 per cent. manganese was covered by a thick reddish-brown ropey metal skin, which in some cases could be peeled off the bar; such a skin may be the surface chill that forms in castings. The colour of bars containing more than 19 per cent. manganese was grey and micaceous rather than brown. There appears to be a slight connection between the expansion of the bars on solidification and the depression in the gate of the casting, a very small or no expansion being accompanied by a gate showing but a small depression, and *vice versâ*.

No mechanical tests were performed on the bars obtained, but during sampling some slight indication of the relative strength under the sledge-hammer was obtained; all were brittle and intensely hard, though with a little labour a fair-sized sample could soon be crushed and passed through a ninety sieve. The addition of the first 5 per cent. of manganese to the white iron produced no appreciable difference in brittleness, but further increase up to about 13 per cent. seemed to give a more brittle bar. Above this amount the bar again appeared stronger, until with 19 per cent. manganese there was quite a considerable increase in the toughness of the specimen. With and above 30 per cent. of manganese the metal partook of the nature of a spiegel, and became very weak and brittle.

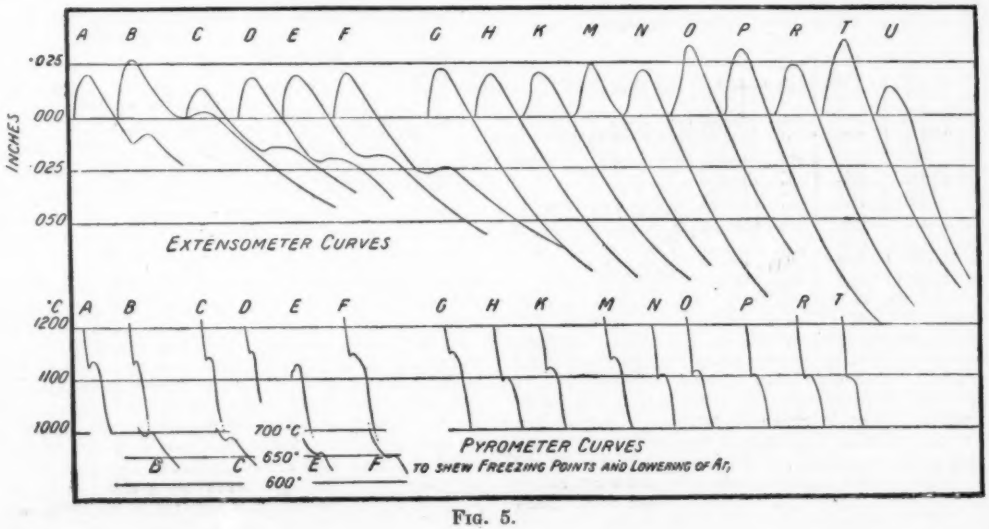

FIG. 5.

An examination of the cast bars showed the pure white iron to possess a white crystalline fracture, with, however, no definite structure; a few per cents. of manganese gave a cruciform structure slightly more

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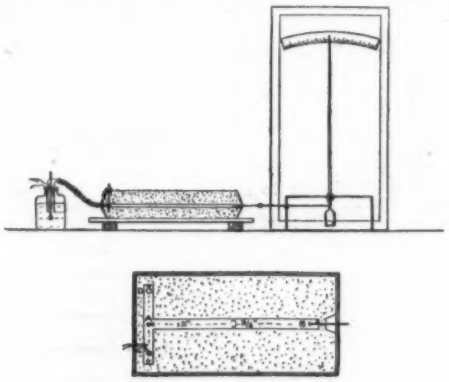

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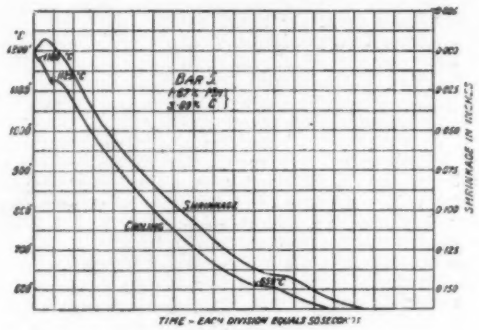

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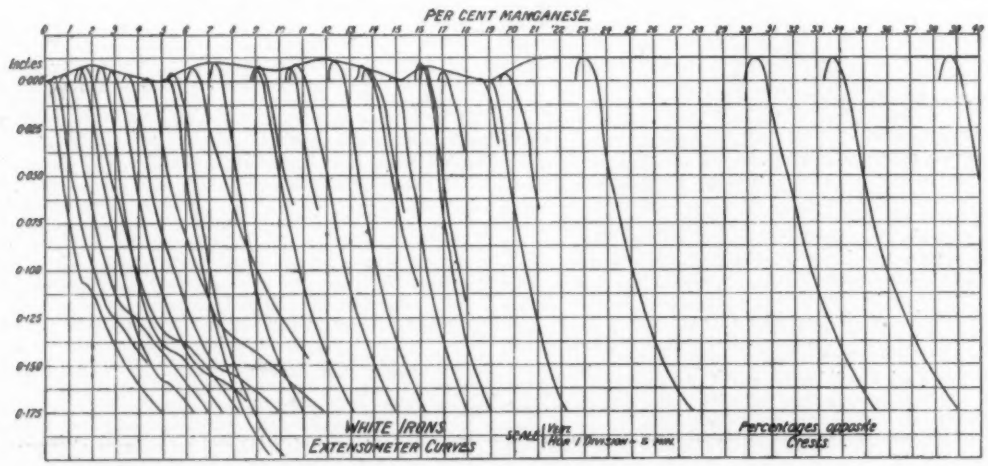

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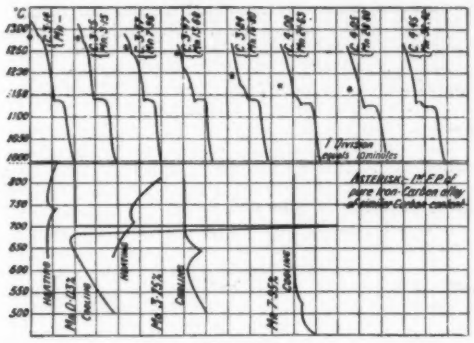

FIG. 3.

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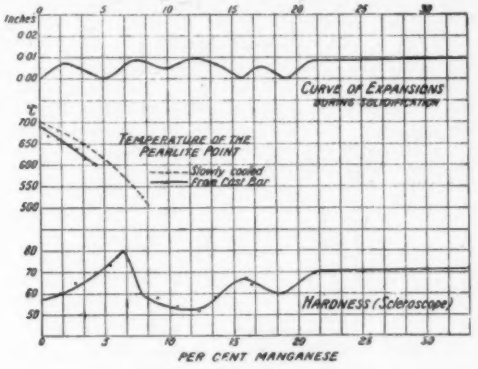

FIG. 4.

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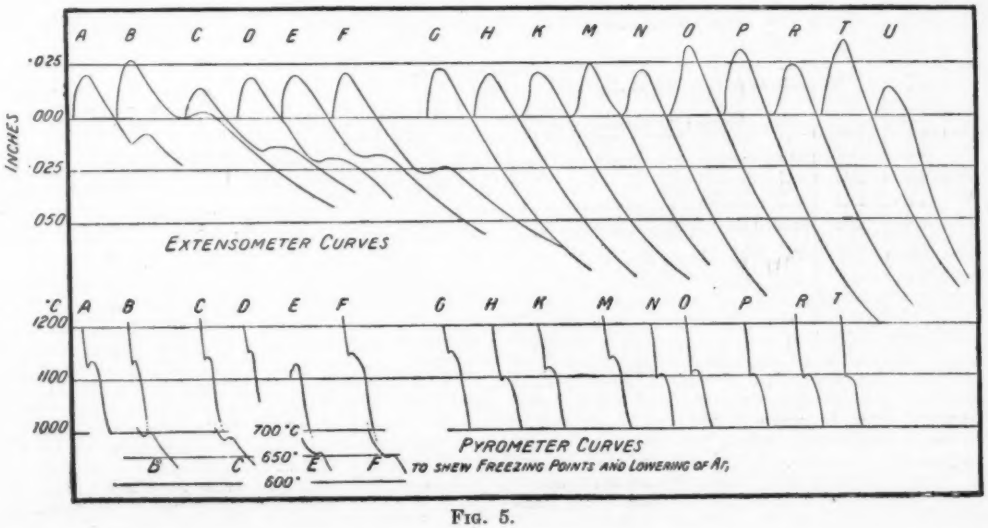


FIG. 5.

per cent. manganese indicates that the surface chilled rapidly, whilst the interior was still fluid; therefore when the gate "piped," the metal surface was unable to follow the movement of the metal underneath, so leaving a cavity in which crystals formed. The surface of bars above 10 per cent. manganese was covered by a thick reddish-brown ropey metal skin, which in some cases could be peeled off the bar; such a skin may be the surface chill that forms in castings. The colour of bars containing more than 19 per cent. bar again appeared stronger, until with 19 per cent. manganese there was quite a considerable increase in the toughness of the specimen. With and above 30 per cent. of manganese the metal partook of the nature of a spiegel, and became very weak and brittle.

An examination of the cast bars showed the pure white iron to possess a white crystalline fracture, with, however, no definite structure; a few per cents. of manganese gave a cruciform structure slightly more

crystalline, and this appearance remained practically unaltered up to 30 per cent. of manganese, when, as stated before, the iron showed a spiegel-like fracture and splits along crystal faces.

The majority of the bars showed dark blue masses of crystallites, which were found particularly at the bottom of the gate, and at the junction of the cross-piece with the bar proper; with over 30 per cent. of manganese these crystallites were replaced by large platey crystals similar to those figured in Howe's "Iron and Steel and other Alloys," p. 90.

The Volume Changes.

The expansions and shrinkages of the bars from the various melts are plotted in Fig. 1A, the crest of each curve being drawn opposite the percentage of manganese in the melt. The curves were carried further than drawn in plate, but show no interesting features below the arrest point Ar_1.

The curve formed by connecting up the crests presents an interesting study. It will be seen that, start-

TABLE I.

No. of Bar.	Carbon.	Manganese.	Silicon.	Inches Expansion.	Remarks.
	Per Cent.	Per Cent.	Per Cent.		
	3·00	40·20	0·14	...	Manganese alloy used.
	3·06	0·035	0·01	...	White iron used.
1	3·13	0·03	0·040	0·0000	Casting full of blow-holes. Spongy gate.
1A	...	...	...	0·0000	Do.
2	3·19	0·43	0·050	0·003875	Full of blow-holes. Slight depression in gate.
3	3·24	0·82	...	0·003886	Full of blow-holes. Spongy gate.
4	3·28	1·43	...	0·006978	Much sounder bar.
5	3·05	1·67	0·055	0·006141	Blow-holes still present. Large depression.
6	3·09	2·37	...	0·007909	Smaller depression in gate.
7	3·19	2·62	..	0·005848	Some blow-holes. Similar depression.
8	3·12	3·50	0·050	0·004071	Sound bar. Large depression in gate.
28	3·14	4·42	...	0·003236	Smaller depression and scoriaceous gate.
9	3·19	5·25	0·061	0·001745	Sound bar. Fairly large depression.
22	3·45	5·40	0·083	0·004652	Sound sharp casting.
10	3·43	6·30	...	0·006878	... ...
19	3·20	7·20	0·081	0·006886	Small depression in gate.
11	3·38	9·00	0·068	0·006978	Hollow gate.
20	3·45	9·13	..	0·006141	Do.
26	3·60	10·40	...	0·006978	Moderately hollow gate.
12	3·46	10·67	0·072	0·006804	Large depression in gate.
22	3·60	12·35	...	0·010467	Do. do.
20	3·49	13·50	...	0·006141	Do. do.
24	3·65	13·70	0·050	0·006397	Small depression.
13	3·41	14·94	...	0·003936	Small depression in gate.
25*	3·60	15·00	...	0·006141	Fairly large depression.
21	3·45	15·20	0·100	0·006978	Small depression.
31*	3·73	17·05	...	0·004071	Fairly large depression.
30*	3·91	18·65	...	0·000980	Large depression.
14	3·38	18·92	0·103	0·00000	Small do.
27	3·81	19·05	...	0·008488	Large hollow in gate under surface.
15	3·85	23·30	0·120	0·011630	Do. Grey skin with green slag.
16	3·95	30·50	0·173	0·011630	Do. do.
17	3·85	34·10	0·186	0·011630	Do. Hollow in gate filled with crystals.
18	3·93	39·55	0·155	0·012211	Do. do.

ing with pure white iron with no expansion, addition of manganese causes an expansion, independently of the carbon; this expansion attains a maximum at about 2 per cent. manganese, after which the curve falls again, probably reaching zero at 5 per cent.; then comes another rise up to 7 per cent. manganese, dipping to 10 per cent., and rising again to 12 per cent., when it commences falling to zero at about 15.3 per cent. Between this and 19 per cent. manganese yet another crest is attained, falling to zero at the latter figure. Further addition of manganese causes another expansion which, with above 21 per cent. of manganese, remains fairly constant up to the limit of the experiments at 39 per cent. manganese.

It will be well to study cooling and shrinkage curves taken simultaneously before attempting to draw conclusions from the general curve of expansions; Fig. 2 shows a normal type of curve drawn on a very small scale from the original data. It appears that the greater part of the expansion is caused by the separation of the primary crystals, and that their later shrinkage is partially neutralised by the solidifying eutectic. When the whole mass is solid, contraction will take place uniformly unless some physical or chemical change occurs in the metal; this fact may afford a means of detecting the "solidus" in alloys—that is to say, when the contraction changes from an abnormal to a normal rate solidification is at an end. In fact, in nearly all the curves drawn, it is found that a sudden change to normal contraction after solidification corresponds closely with the change to normal cooling, as is exemplified fairly well in Fig. 2.

The shrinkage curves for bars containing less than 5 per cent. of manganese show an arrest between 700 degrees C. and 600 degrees C., corresponding to the separation of carbide from solution in the form of pearlite. This arrest undoubtedly occurs simultaneously with the arrest in the cooling curve; it usually commenced a little before or a little after the cooling curve arrest, but this is probably due to the pyrometer not registering quite the mean temperature of the bar in all cases.

In this series it is doubtful whether the arrest in the shrinkage is merely a consequence of the evolution of heat at Ar_1, or a separate phenomenon in itself, but on this point more definite information is attained in the case of the grey irons.

Pyrometric Results.

As already stated, the couple was in contact with the fluid metal, and in most cases this seemed to give

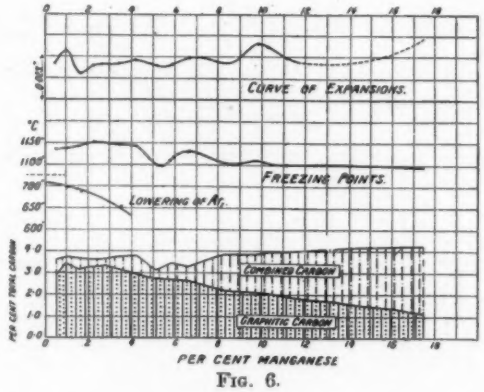


FIG. 6.

satisfactory results; for example, the solidification point of pure white iron was registered at 1,132 degrees C.; but although the eutectic point was usually recorded fairly correctly, the first arrest due to the separation of primary crystals was in all cases given at least 100 degrees C. below the theoretical figure, and also below the figure given on a slow-cooling curve. Again, at about 19 per cent. manganese, the eutectic point was found in three cases to be about 1,080 degrees C., which appeared so strange that ordinary slow-cooling curves were taken, for which purpose about 200 grammes of metal were melted in a gas-injector furnace, and a thermo-couple protected by a porcelain or fireclay tube inserted in the mass, which was then allowed to cool, readings being taken every half-minute.

Table II. gives the pyrometric results obtained from remelted samples of various bars, together with the analyses of the resultant buttons; the cooling curves obtained are reproduced in Fig. 3.

It is at once seen that the anticipated lowering of the eutectic point in alloys containing about 20 per cent. manganese is not found, but that further addition of manganese does produce a slight fall, amount-

ing to about 15 degrees C. with the addition of some 29 per cent. manganese. The cooling curves are interesting as regards the temperature at which the primary crystals separate; the asterisks in Fig. 3 indicate the temperature at which primary crystals commence to separate out in a pure iron-carbon alloy of similar carbon content.* With the pure washed iron there is no great divergence (5 degrees C.) between the theoretical and the observed temperature, but observations in the case of the manganese alloys immediately show that manganese acts like carbon and lowers the temperature of the separation of the primary crystals, this lowering amounting to about

TABLE II.

No. of Bar.	Total Carbon.	Manganese.	Silicon.	First Arrest.	Second Arrest.	Pearlite Point.
	Per Cent.	Per Cent.	Per Cent.			
1	3·14 { gr. 1·67 c.c. 1·27	0·025	0·01	1285	1139	700
28	3·15	3·75	0·27	1270	1141	645
11	3·27	7·25	0·17	1247	1140	595
13	3·47	13·60	0·22	1204	1140	...
14	3·64	16·80	0·26	1160	1141	...
15	4·00	21·63	0·33	1140	1130	...
16	4·05	28·80	0·41	...	1125	...
17	4·45	33·43	0·42	1138	1125	...

40 degrees C. with 13 per cent. manganese, above which the effect appears to diminish slightly.

Pyrometric observations indicate pure eutectic with about 28.8 per cent. manganese and 4.05 per cent. carbon, though later microscopic investigation proves such an alloy to be somewhat hyper-eutectic. In other words, these results show that one effect of manganese on cast iron is to move the line AB of the ordinary iron-carbon equilibrium diagram slightly to the left.

The condition of the carbon in the pure washed iron is interesting, though it should be remarked that the metal was heated up twice to 900 degrees C., and then very slowly cooled; the alloy with 3.75 per cent.

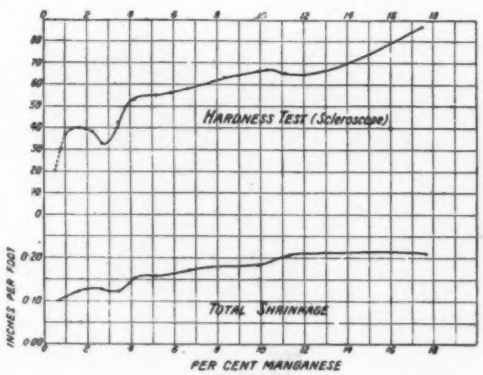


FIG. 7.

manganese, which was treated in the same manner, remained, however, perfectly white.

The effect of manganese on the temperature of the pearlite point has been studied by several investigators, particularly in regard to manganese steels. Wüst† finds that each 1 per cent. of manganese added lowers the pearlite point by 20 degrees to 24 degrees C. in the case of carbon-saturated manganese-iron alloys, the arrest finally disappearing with 5 per cent. manganese;

* Carpenter and Keeling, "The Range of Solidification and the Critical Changes of the Iron-Carbon Alloys," "Journal of the Iron and Steel Institute," 1904, No. I., p. 224.

† "The Influence of Manganese on the Iron-Carbon System," "Metallurgie," 1909, p. 3.

and this was confirmed by results the author obtained from the cast bars, as is seen in Table III.

Furthermore, a study of the actual curves indicates that not only is the temperature of the pearlite point lowered, but also that the heat evolution at this point is diminished and spread over a range of temperature. These latter facts were confirmed subsequently by taking temperature observations on a potentiometer of the slowly cooled remelted bars (Fig. 3). It was found, however, that the lowering caused by the addition of the first 3.75 per cent. manganese was not so great as that found from the cooling curves of the

TABLE III.

No. of Bar.	Manganese.	Temperature of Pearlite Point.
	Per Cent.	
1	0·03	691° C.
2	0·43	687
3	0·82	669
4	1·48	662
5	1·67	659
6	2·37	646–642
7	2·82	638–635
8	3·50	619–615
28	4·42	620–587
9	5·25	Undetected at 400° C.

cast bars. The arrest was detected at 525 degrees C. in the alloy containing 7.95 per cent. manganese; microscopic examination would indicate the presence of this arrest with as much as 10 per cent. manganese in the alloy. The hysteresis of the pearlite point was 40 degrees C. in the case of the pure washed iron, and 65 degrees C. for the specimen containing 3.75 per cent. manganese.

Microscopic Investigation.

A suitable specimen was broken off each bar and a flat face ground down on a water-cooled emery wheel,

TABLE IV.

Minimum.	Iron	Manganese.	Carbon.	Carbon as Carbide.	Composition of Carbide.	Probable Formula of Carbide.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.		
1	96·8	..	3·15	47·3	C 3·15 Mn Fe 44·15 47·3	Fe_3C
2	91·8	5·0	3·19	47·9	C 3·19 Mn 5·00 Fe 39·71 47·90	$8Fe_3C.Mn_3C$
3	81·1	15·3	3·41	51·15	C 3·41 Mn 15·30 Fe 32·44 51·15	$2Fe_3C.Mn_3C$
4	76·5	19·0	3·38	50·7	C 3·38 Mn 19·00 Fe 28·32 50·70	$3Fe_3C.2Mn_3C$

after which rubbing was performed by hand on coarse emery paper, and then on Hubert papers 0 to 0000, the final polishing being done on a revolving pad of chamois leather, using the finest alumina as the polishing agent. The specimen was washed and cleaned and immersed in a 5 per cent. solution of picric acid in absolute alcohol for a period varying between three and ten seconds according to the nature of the specimen.

The structure of the solid solution only was desired in most cases, so that the majority of the photographs were taken at 1,000 diameters, vertical illumination.

The general dendritic structure was shown up without etching, and in the high-manganese alloys the bands of carbide, referred to later, could be easily

distinguished by the naked eye; slight etching showed primary crystals as dendrites in a matrix of eutectic and of cementite thrown out round the edges of the solid solution during cooling. Small triangular crystals of pale yellow sulphide of iron were observed in the

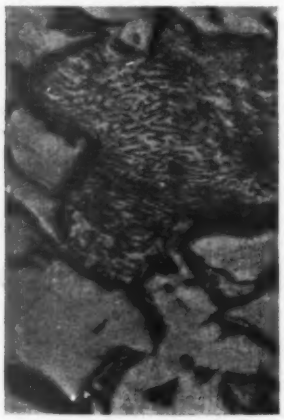


FIG. 8.—BAR 1. 1,000 DIAMETERS. 0.03 PER CENT. MN; 3.15 PER CENT. C. PEARLITE + EUTECTIC.

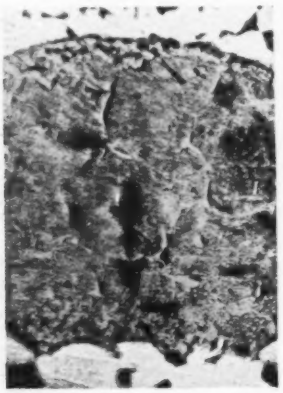


FIG. 9.—BAR 28. REMELTED AND SLOWLY COOLED. 1,000 DIAMETERS. 3.75 PER. CENT. MN; 3.15 PER CENT. C. FINE GRANULAR PEARLITE.

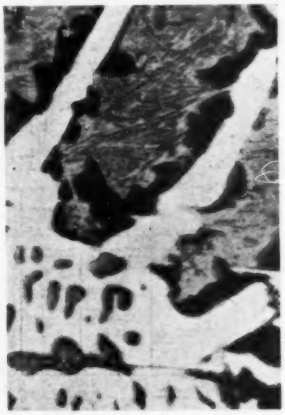


FIG. 10.—BAR 9. 1,000 DIAMETERS. 5.25 PER CENT. MN; 3.09 PER CENT. C. CEMENTITE NEEDLES, THROUGH SOLID SOLUTION. SORBITIC FRINGE.

cementite areas of the pure washed iron, but the smallest addition of manganese converted them into dove-grey square crystals of manganese sulphide.

The structure of the original iron was typical of white irons, and shows well-defined lamellar pearlite (Fig. 8). One per cent. of manganese makes the pearlite distinctly finer, and further addition increases this effect until with 3.45 per cent. the eutectoid consists of sorbitic and granular pearlite. Apart from the change in the appearance of the pearlite, it is interesting to note that with ½ per cent. of manganese, the pearlite is veined by streaks of carbide, and further increase in manganese develops this structure, until with 4.40 per cent. canal-like bands cross the pearlite in more or less parallel directions, debouching into the cementite on each side. Such an appearance is presented by all further specimens up to 30 per cent. manganese, at which these dendritic primary crystals disappear.

Manganese, then, appears to lower the diffusive power of the carbide so that, on cooling from 1,000 degrees C., instead of being driven to the edges of the solid solution it separates in the solid solution itself. This is probable, as photographs Figs. 10 to 14 show the bands forming quite a rectilinear structure. It may be noted that in some cases these bands exhibit a crooked appearance, as if the metal had

FIG. 11.—BAR 10. 1,000 DIAMETERS. 6.30 PER CENT. MN; 3.43 PER CENT. C. RECTILINEAR CEMENTITE NEEDLES, THROUGH SOLID SOLUTION. SORBITIC FRINGE.

FIG. 12.—BAR 10. 400 DIAMETERS (AS BEFORE).

FIG. 13.—BAR 19. 1,000 DIAMETERS. 7.20 PER CENT. MN; 3.39 PER CENT. C. RECTILINEAR STRUCTURE. FORMED BY NEEDLES OF CARBIDE.

undergone deformation. Fig. 9 of a slowly-cooled alloy displays the decreased mobility of the molecules of carbide in a very striking fashion.

When the manganese exceeds 5 per cent. these bands or needles give quite a martensitic appearance to the solution (Fig. 10). Around the borders of this material there is a dark grey constituent which is quite sharply defined from the general mass of the solid solution; in parts it appears vaguely pearlitic, and probably represents a breaking down of the solution.

FIG. 14.—BAR 14. 400 DIAMETERS. 18.92 PER CENT. MN; 3.38 PER CENT. C. GENERAL STRUCTURE OF ALLOYS.

Fig. 10, 11, and 13, at 1,000 diameters, and Fig. 12 at 400 diameters, show this fringe, which, however, with increase in manganese gradually disappears and is not observed beyond 10 per cent. The character of the solid solution does not afterwards change appreciably, and Fig. 14 gives the general appearance at 400 diameters; there is a tendency for the proportion of eutectic to increase independently of carbon.

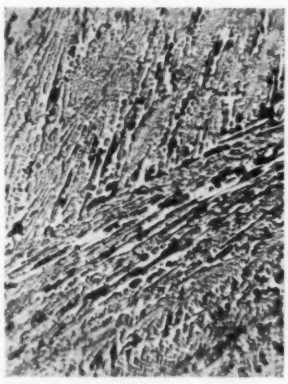


FIG. 15.—BAR 16. 100 DIAMETERS. 30.5 PER CENT. MN; 3.95 PER CENT. C. NEARLY PURE EUTECTIC. COARSE CRYSTALLINE STRUCTURE.

The structure of the alloy with 30 per cent. manganese is totally different, as is seen in Fig. 15, which shows at 100 diameters fairly pure eutectic, with perhaps a slight excess of the white constituent; also a rectilinear structure may be observed.

Further increase of manganese causes the appearance of bands of free carbide in addition to the eutectic, as shown in Fig. 17 (33.6 per cent. manganese), and this in spite of the carbon content being even slightly lower; these bands are beautifully defined, can be traced clearly with the naked eye, and are undoubtedly equivalent to the platey crystals occurring in the cast materials. The section of Bar 18 (38.55 per cent. manganese) is similar, but shows a larger number of the bands.

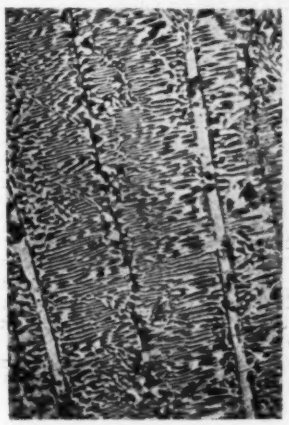


FIG. 16.—BAR 16. REMELTED AND SLOWLY COOLED. 100 DIAMETERS. 28.8 PER CENT. MN; 4.05 PER CENT. C. SLIGHTLY HYPER-EUTECTIC.

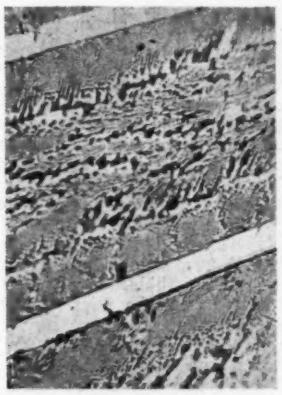


FIG. 17.—BAR 17. 100 DIAMETERS. 34.1 PER CENT. MN; 3.85 PER CENT. C. EUTECTIC + BANDS OF CARBIDE. Fe_3C, Mn_3C.

Interpretation of Results of Expansion Curves.

The curve of expansions is drawn in Fig. 4, so that it may be compared with the general experimental data obtained for the alloys. Minima on the expan-

sion curve are found with:—(1) The pure American washed iron; (2) the same with about 5 per cent. manganese added; (3) with about 15.3 per cent. manganese added; (4) with 19 per cent. added. Above 19 per cent. there was no indication of another minimum as far as the experiments were conducted—that is, up to 39 per cent. manganese. With regard to the general expansion curve, two remarkable points may be observed.

(1) That the first minimum at 5 per cent. corresponds with the disappearance of uniform pearlite.

(2) That at 30.5 per cent. manganese, where there is practically pure eutectic, the expansion is great, and apparently not altered by moderate increase or decrease of manganese.

It will be assumed for the sake of simplicity, since no graphite enters into the question, that the iron iron-carbide system is the stable one in the case of these white irons. Now bearing in mind the general opinion that manganese occurs in the presence of iron and carbon in the form of double carbides, this curve of expansions will immediately strike one as giving indications of certain definite carbides—in fact, that minima on the curve correspond to the occurrence of pure double carbides.

The author wishes to note here that exact minima are not found on the curves at 5 and 15 per cent. manganese, not because they do not exist, but because, for reasons stated previously, it is not an easy matter to obtain any desired exact composition. The compositions of the metals at or near these minima are known, and a simple calculation of the amount of carbide present may be made, and in consequence the amount of metal forming this carbide. It is sufficiently accurate to say that to form carbide, 1 gramme of carbon combines with 14 grammes of metal, whether it be iron or manganese (see Table IV.). Now if all the manganese added enters this carbide, it is easy to find out the quantity of iron with which it is associated.

The first of the double carbides corresponds closely to that found by Arnold and Read in a steel containing 1.73 per cent. manganese, and to which they gave the formula $7Fe_3C.Mn_3C$.; again, Carnot and Goutal discovered a carbide corresponding to the formula $2Fe_3C.Mn_3C$ in ferro-manganese containing 30 to 60 per cent. manganese. The carbon in these latter alloys, however, was very much higher than in the author's experiments, so perhaps accounting for the difference in manganese content. More recently Messrs. Arnold & Read have detected the presence of the double carbide $2Fe_3C.Mn_3C$ in manganese steels containing 15 per cent. manganese. Apparently the carbide possessing the formula $3Fe_3C.2Mn_3C$ has not been isolated. The double carbides are undoubtedly isomorphous, and form solid solutions amongst themselves and with iron-carbide, since they cannot be detected separately under the microscope.

The dip in the curve at about 10 per cent. manganese may be due to yet another double carbide, $4Fe_3C.Mn_3C$, but the evidence is too slight to place this one in the list, although such a carbide was found by Carnot and Goutal, yet even here the evidence they possessed indicating its existence was not conclusive.

The alloys containing from 30.5 to 39.5 per cent. manganese present some very interesting features; the structure with 30.5 per cent. manganese and 3.95 per cent. carbon shows almost pure eutectic, as is seen in Fig. 15; there is perhaps a little excess of carbide, but this may be due to segregation, as the appearance of the eutectic in Fig. 17 is similar. When, however, portions of Bar 16 (30 per cent. manganese) are remelted and cooled slowly, further evidence is obtained; the resultant melt contains 28.8 per cent. manganese and 4.05 per cent. carbon, and under the microscope is somewhat hyper-eutectic, as is seen in Fig. 16, which shows a very coarse and beautiful eutectic with some thin bands of free carbide.

Guillet found an alloy containing 15 per cent. manganese and 3.6 per cent. carbon to consist of practically pure eutectic, while Wüst gives 16 per cent. manganese and 4.05 per cent. carbon as the eutectic composition. In the author's research an alloy similar to the former composition shows large masses of primary crystals; while with regard to the latter composition it may be stated that a slowly-cooled alloy containing 21.6 per cent. manganese and 4 per cent. carbon was distinctly hypo-eutectic as indicated both by the microscope and by the cooling curve. The eutectic alloy probably contains 26 to 28 per cent. manganese when the carbon is 4.05 per cent. This 4.05 per cent. carbon exists as $4.05 \times 15 = 60.75$ per cent. carbide, made up of 4.05 per cent. carbon, 26 to 28 per cent. manganese, and 30.5 to 28.5 per cent. ferrite, corresponding approximately to the double carbide $Fe_3C.Mn_3C$. The metallography of the cast bars indicates that manganese, independently of carbon (see analyses), gives rise to free carbide in the form of bands, as a comparison of Figs. 15 and 17, will show; and so the question arises: How can free carbide occur while the carbon is even lower than in the previous bar which shows practically pure eutectic?

It is probable that when the double carbide $Fe_3C.Mn_3C$ is formed, the avidity of the excess manganese for carbon is diminished, and instead of combining to form a double carbide, $xFe_3C.yMn_3C$, where y is greater than x, the manganese associates itself with the iron of the solid solution to form the solvent of the carbide. A new state of equilibrium is set up, and the eutectic point of the ordinary iron-carbon equilibrium diagram is shifted towards the left, thus permitting free carbide to separate as primary crystals.

The Relative Hardness.

The instrument used for determining the hardness of the specimens was the Shore scleroscope. Specimens were broken off the bars, and two parallel sides ground down on an emery wheel and then roughly polished. Table V. gives average figures of more than a dozen determinations from each specimen.

TABLE V.

Manganese. Per Cent.	Hardness Value.	Manganese. Per Cent.	Hardness. Value.
0.03	58	12.35	52
1.48	60	13.50	58
2.82	65	16.00	67
4.40	70	16.20	64
5.40	73	18.65	60
6.30	80	23.30	70
7.20	59	30.50	70
9.12	58	34.10	71
10.67	54	38.55	72

These figures are drawn to their manganese equivalent in Fig. 4, from which it will be seen that the first addition of manganese produces a sharp rise to 6.3 per cent., then a sudden drop ensues to 12 per cent., after which there is a rise to 23 per cent.; further addition of manganese does not seem to influence the hardness very appreciably.

The Shrinkage of the White Irons.

No determinations of total shrinkages were made; it was found by measurement that the rate of shrinkage per 100 degrees C. above the pearlite point was practically the same as the rate below it (compare the grey irons).

(To be continued.)

A New Electric Furnace for Steel Melting and Refining.

By J. Harden.

The electric steel furnace appears to be steadily gaining ground in this country, and amongst others a 1½-ton Kjellin induction furnace has recently been erected in Sheffield, for crucible steel work, and has successfully completed its guarantee run. This furnace is especially adapted for producing the highest grade of tool steel. It is, however, well-known that a furnace of this type is not adaptable for any extensive refining of steel, owing to the refining surface of the bath being small.

It has long been recognised by steel-makers generally that although the induction furnace is an excellent tool in the hands of the crucible-steel-maker, a furnace which would permit more extensive refining, and also the construction of large units, at the same time keeping the advantages embodied in the induction furnace system, is much to be desired. It is because of the comparatively low power-factor of larger furnaces of the plain induction type that this class of furnace has not been constructed in large units to any great extent.

In order to overcome this, the Röchling-Rodenhauser furnace, which is partly a resistance furnace and partly an induction furnace, was designed. A considerable number of these furnaces have been erected and are in operation abroad, giving very good results. Many steel-makers, however, are of the opinion that it would be an advantage if a furnace could allow superheating the slag for refining purposes, but at the same time enable the metallurgist to so regulate the heat of the charge that gases could be expelled without difficulty. At the same time, the perfect circulation of the bath should be maintained so as to secure a perfectly uniform material.

A new furnace on these line, which the inventors call the "Paragon" furnace, has been designed and protected by patents, which appears to possess points in its favour. As is shown in Figs. 1, 2, and 3, this furnace is a combination of an arc and a resistance furnace, which makes it very much like an open-hearth furnace, and it may indeed be worked exactly in the same manner. The slag blanket is kept at the desired temperature by means of arcs playing over the surface of the slag, while the remainder of the heating power is transmitted to the bath by means of terminal plates, such as are used in the Röchling-Rodenhauser furnace.

The result of this combination is that the slag may be heated to any desired temperature while de-phosphorisation and de-sulphurisation takes place, but the heating effect of the arcs need not be increased to such an extent as to keep the whole charge superheated, which, of course, would tend to overheat the steel immediately beneath the arcs, but a carefully regulated amount of current can be at the same time sent through the resistance plates, thus also heating the charge from underneath.

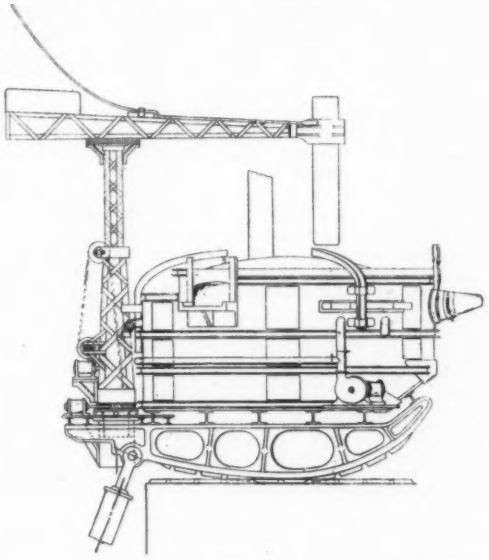


FIG. 1.—ELEVATION OF "PARAGON" ELECTRIC FURNACE.

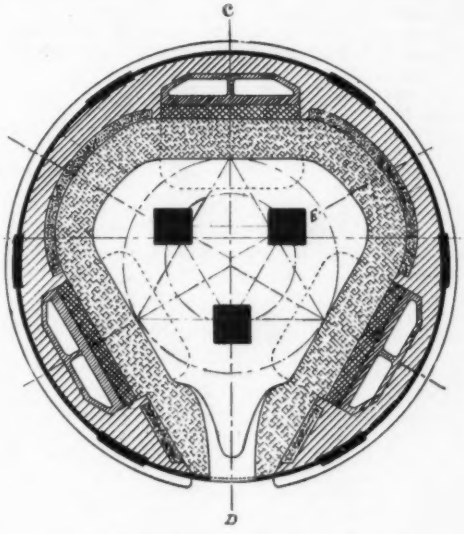


FIG. 2.—SECTIONAL PLAN OF HEARTH, ON C. D., FIG. 3.

When the de-phosphorisation and de-sulphurisation is finished, it may be desirable to alter the gradient of heat in the furnace so that the lower portion of the bath is hotter than its surface, in order to expel the gases more readily. This result is obtained by diminishing the power transmitted through the arcs and increasing the power transmitted to the side plates. In fact, it is even possible to extinguish the arcs for a time and keep the bath liquid by means of the side plates, which for this purpose are provided with a cooling device of enforced air. The metallurgist has therefore the power of controlling the gradient of heat in the bath at will.

This combination has another advantage, viz., that the electrodes do not require to be of such large sec-

tion for a given capacity of furnace as would be the case if the total amount of power were transmitted by means of the arcs only, owing to the fact that normally about 50 per cent. of the total power is transmitted through the arcs while the other 50 per cent. is transmitted through the side plates. The advantages claimed, therefore, are threefold.

Firstly, the size of electrodes for a given furnace capacity is only about half that of an arc furnace, and consequently with a given electrode section available the melting capacity of the furnace can be nearly doubled.

Secondly, owing to the destructive effect of large arcs immediately under the roof of the furnace, the roof very quickly deteriorates, but in the case of this new furnace the roof is not subjected to such severe strain owing to the reduced size of the electrodes and to the smaller amount of power transmitted through the arcs; therefore the maintenance of the furnace costs less, and the roof lasts longer.

Thirdly, the control of the load-factor of the furnace is better, because the current flowing through the resistance plates is a perfectly steady one, whereby the heavy current fluctuations otherwise caused by large arcs is very extensively compensated.

The result of this is that no special machinery is required either for compensating for the lower power-

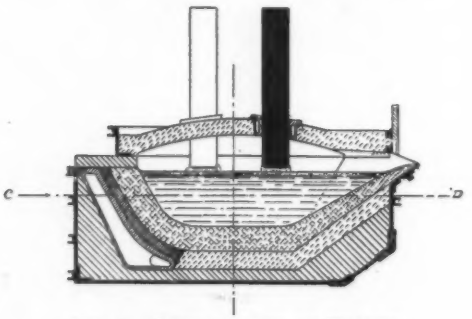


FIG. 3.—CROSS SECTION OF HEARTH ON C. D., FIG. 2.

factor of a true induction furnace or designed with a large flywheel effect, as in the case of a simple arc furnace, on account of its fluctuating load-factor. Standard machinery and standard transformers only appear to be necessary.

The power consumption per ton of steel should also prove more economical by means of this combination, as the high temperature of the steel is only required during de-sulphurisation, it being well-known that de-phosphorisation does not require such a hot slag as de-sulphurisation, and it follows as a logical sequence that the higher the temperature of the steel for any length of time, the greater also the heat losses during the process; in view of this, the total melting and refining process should be more economical with this combination. It therefore appears that this type of furnace includes several of the advantages of the induction furnace, viz., a good circulation of the charge, inasmuch as it is heated from below as well as from above, and a high load-factor.

No electrical apparatus, in the ordinary sense of the word, seems to be an element of the design of this furnace, because the power supply transformers may be situated in an adjoining building protected from dust and injury, and entirely beyond the reach of the workmen.

The regulation appears to be simple, as if the furnace is operated direct from a generator, the field rheostat controlling the current to the generator is all that is required; or, if transformers are used in connection with an existing power supply, so-called regulating transformers with interchangeable terminal steps are employed.

The author is informed by the owners of the patents, Messrs. The Gröndal Kjellin Company, Limited, that furnaces of this type will shortly be tried.

Castings as Igneous Rocks.

Professor A. McWilliam, M.Met., A.R.S.M., of the University of Sheffield, before the Sheffield Branch of the British Foundrymen's Association, on Tuesday, December 13, 1910, delivered a lecture on "Castings as Igneous Rocks." Samples of typical igneous rocks rocks were shown of the same chemical composition, but varying from the almost pure glass of Obsidian through the ill-defined feathery-like minerals of pitchstone and the fine but complete crystalline grouping of the constituents in Eurites, to the completely crystalline forms of granite, in which the crystals are easily visible to the naked eye. Reference was then made to the fact that igneous rocks were found of different compositions, and when entirely crystalline with minerals well defined, as in the case of granite, their compositions give such rocks as Syenite and Gabbro, but if the cooling of rocks of any of these compositions were sufficiently rapid, they would all give glassy materials just like Obsidian. The glassy rock is the result of comparatively quick cooling, the granite of extremely slow cooling, but whereas the quick cooling of rocks might occupy years, the quick cooling of steels, as represented by quenching, is a matter of seconds. Allowing for these differences in times, most of the changes in structure that are found in the igneous rocks of the earth's crust have their analogues in castings variously heat-treated.

The obsidian-like structure of a 0.9 per cent. carbon hardened steel was compared with the granite-like appearance under the microscope of a slowly-cooled steel casting. The presence of a prominent crystal of orthoclase in a trachyte reminded one of the gathering into a condition of slow cooling. But the analogy must not be carried too far in a blind and reckless fashion. In the cavities of granite the crystals grow and show their true external form just as in the cavities of very large ingots cystals of iron are found. After several other illustrations, the lecturer then took his audience through some of the changes that take place from the homogeneous molten state to the solid casting in the cases of white cast iron, grey cast iron, steel castings cooled in the mould, slowly cooled, and quenched at different temperatures. He also showed with regard to case-hardening and to burning, as in the rocks so in the castings, for good or ill, one substance may diffuse in carbon in case-hardening, or may got out, decarburising on the surface; or oxygen may come in, remove the carbon and leave an oxide to the detriment of the whole material, as in burnt steel or an aired bar. The importance of studying changes after solidification such as those that occur in rocks known as metamorphic, where the magnetite gathers together in the masses that are the source of the famous Swedish iron so much used in Sheffield, was further illustrated by the growth of free carbon by the heat treatment of white iron. The nature, distribution and size of this free carbon is of the utmost importance in its effect on the properties of commercial malleable cast iron.

Finally, the powerful influence of small quantities of impurities in preventing the formation of the quite useless blown metal, and the differences in after treatment, were illustrated by slides.

Patterns for Gear Wheels.

By Chas. A. Otto.

The writer proposes to describe various ways of making gear patterns. Many wheels are cast blank, and the teeth afterwards cut out by machinery; there are also wood-working machines capable of forming the correct shape of teeth, but the object of this article is to describe methods when these machines are not available.

Construction of Spur Wheels.

The general method of building up a spur wheel is shown in Fig. 1. The rim should be built up and

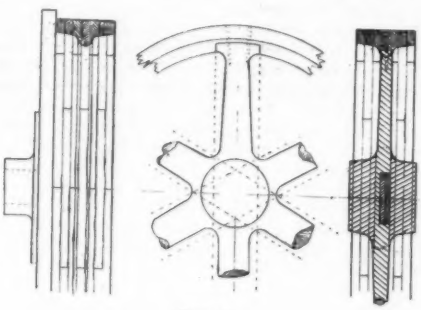


Fig. 1.

turned in the usual manner with just a perceptible taper on the outer diameter and slightly more on the inner diameter on each side of the arms. Portions from the inside of the rim are cut out to receive the arms, which may number four, five or six, according to the size of the wheel required. When there are more than six arms the wheel patterns are usually made in a different manner. The arms are joined together as shown in Fig. 2, and made to fit the rim. When this is accomplished, they are glued

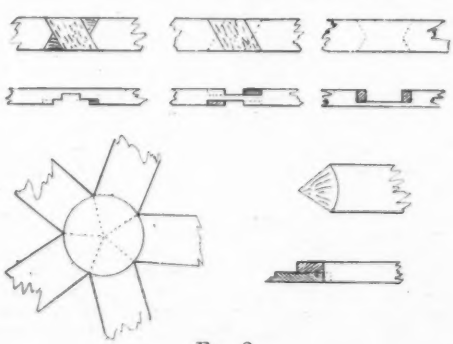


Fig. 2.

and dowelled in their places. The centres are struck off for the number of teeth required on the outer diameter, and with the aid of a surface plate (if not available, the saw bed answers the same purpose), the centres are squared across the full width of the rim. The edge of the rim is not to be depended upon for squaring purposes.

Should the pattern be required for standard work the most accurate wheel would be made by fastening to the outside of the rim a piece of wood for each tooth, either by dovetailing and glueing, or simply by nailing or glueing, as shown in Fig. 3. These methods, however, are expensive, and take up too much time for urgent work, because each tooth would necessarily have to be marked off separately, whereas a much quicker method to adopt is that employing a jig. Fig. 4 shows such a jig for a tooth formed by cycloidal curves. The opening in the jig ought to be the exact length of the teeth across the face of the wheel, and this should be cut out after the block has been made the required shape. The jig is made

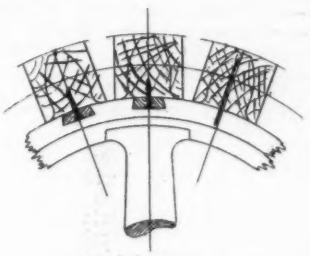


Fig. 3.

from two pieces of hard wood, which are attached to each other by means of a long dovetail, this saving unnecessary work with the vice. In the opening which is cut out to receive the small blocks for the teeth, the base of which is convex, two small sprigs are inserted, the points being allowed to project about $\frac{1}{8}$th of an inch. A number of blocks for the teeth are cut out, about four or five more than are actually required, trimmed to the exact length of the opening in the jig, and gouged on one side until they fit the outside diameter of the rim.

These blocks are then shaped separately by placing each one in the jig and securing it by a screw from the back and following the contour of the jig with gouge, chisel or planes. A great deal of care is

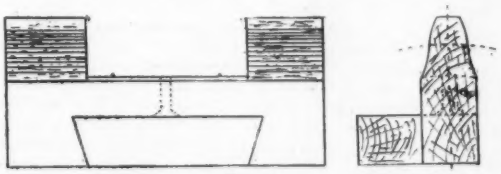


Fig. 4.

necessary in attaching these teeth to the rim; they should be glued and nailed with the edges following the squared lines marked on the rim, and as a precaution, tested with a pair of fine callipers set to the correct pitch. The facings and print can now be screwed on to form the hub, thus finishing the pattern.

Bevel Wheel Patterns.

The rim of a bevel wheel should be built up of segments in a manner similar to the method used in the building of the rim of a spur wheel, except that, owing to the conical form of the rim, no two series of segments are the same diameter. Fig. 5 shows the

iron face-plate of the lathe with a wooden face-plate attached to it, and the section of a wheel built up of four courses of segments. The outline of the rim is drawn on the segments showing the amount of wood to be turned off in finishing this portion of the pattern. After the rim is built up and attached to the face-plate, the inside surface should be turned, and a chuck should then be turned to fit the inside of the rim, and to which the rim is fixed, so that the outside or face can be turned ready to receive the teeth.

It is advisable to strike the centres of the teeth or the base lines before removing the rim from the lathe. Spaces corresponding to the number of the teeth should be stepped off on the face near the outer diameter. A block is next attached to the centre of the

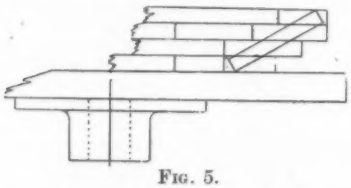


FIG. 5.

chuck, allowing it to project far enough to contain the apex of the cone of which the rim is the frustum. The block is shown on Fig. 6. The point of the block should be turned so that it will form a portion of the surface of the cone, of which the rim is a portion. Next knock an ordinary pin into the apex, allowing it to project about $\frac{3}{4}$ of an inch. Then by placing a straight-edge against this pin lines can be drawn through the points already marked on the rim. The teeth can then be formed in a similar manner to that previously explained, and attached to the face before taking it from the chuck. The root of each tooth should be set to the radial lines, and the teeth should be tried with callipers and with a straight-edge from the apex of the cone. The arms and ribs can then be set off, the former by letting into the smallest series of segments and the latter by simply cutting to follow the bevel of the inside part of the rim.

The method of developing the outline of the tooth at the outside and inside faces of the wheel, also at

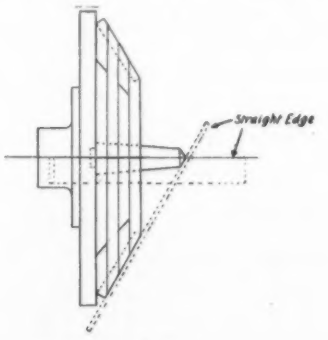


FIG. 6.

the outer and inner ends of the jig is shown in Fig. 7. The number of teeth in a bevel wheel is the number on the working pitch diameter or radius C.D., but this number is not used in laying out the tooth outline. In developing the curves for the tooth, the number of teeth in a wheel of corresponding pitch, and having a pitch radius equal to the back conical radius or B.E in Fig. 7 is used. In order to lay out the teeth it is first necessary to draw a section of one-half of the wheel, as shown in Fig. 7, the pitch radius of the wheel being C D, and the face conical radius being A B. A line is next drawn perpendicular to A B at the point D, intersecting the centre line of the wheel at the point E. This will give the back pitch radius B E. It is then necessary to lay off the height or length of tooth Z, and draw radial lines extending beyond the ends of the teeth. The spaces X X correspond to the portions of the jig at each end of the tooth, and it will be necessary to determine the outline of the tooth for both the outer and inner ends of the face of the tooth proper.

With A as a centre, and the radius A B, an arc is described, and several teeth marked off with the given circular pitch, the thickness of the tooth W marked off, and radial lines drawn through these points. This will give the thickness of the tooth and the circular pitch at the ends of the jig and at the smaller end of the tooth. It should be noted that all lines on the face of the tooth, whether at the top, bottom, or any point on the side, including the base line, all meet at the apex A.

With E as a centre, and B E as a pitch radius, the pitch line is drawn, and several teeth set off with the given circular pitch. It is then necessary to lay off the thickness of the teeth on this pitch line and

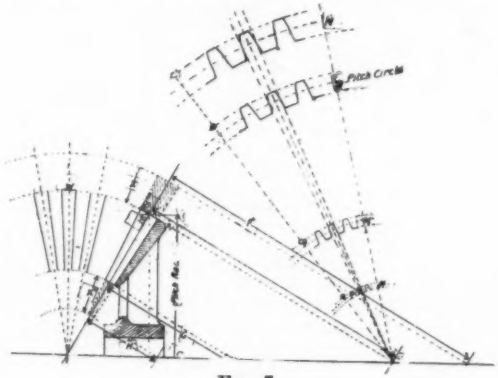


FIG. 7.

draw in the addendum, root, and base circles with the aid of an odontograph (this has already been explained in the FOUNDRY TRADE JOURNAL, March, 1909).

As the tooth outline is taken from the back conical radius, it should be calculated as follows:—Multiply radius B E by two for diameter, and then by 3.1416 for the circumference of the pitch circle used in determining the form of the tooth. Divide this circumference by the circular pitch to get the number of teeth. It should be noted that in dividing the circumference of this construction pitch circle, the result will rarely be a whole number, therefore the nearest whole number is taken as the number of teeth. Having found the number of teeth we would look in the odontograph table and opposite this number we would find the factors to be used in drawing the tooth outline. From the odontograph table the radii to be used in drawing the face and the root of the teeth should be found, and the centres O O and N N determined. With pitch radii equal to the lines F, G, and H and E as a centre, draw pitch circles for the outer end of the jig, inner end of the tooth and inner end of the jig, as shown in Fig. 7. Next draw the radial lines through the points O O and N N, which will determine the centres to be used in drawing the face of the teeth corresponding to each of these different radii. Of course, the addendum, root, and base circles should be drawn in each case in their proper relationship to the pitch circle.

When the wheel is so large that it is not convenient to determine the length of the back radius by drawing it out for the large and small ends of the teeth and jig, these radii can be calculated in the following manner:—If it is desired to calculate the back radius B E corresponding to a wheel having the pitch radius C E, first subtract from 90 degrees the angle formed by the intersection of the back radius B E with the face radius A B, the angle formed between A B and the centre line of the wheel, divide the sine of the difference of these two angles into C B, and the result will give the back radius B E. Having

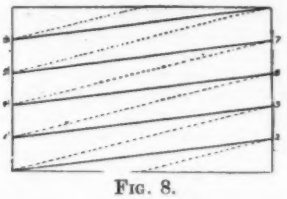


FIG. 8.

obtained this radius, calculations are next made for the outline of the tooth at the large end, as already explained. The outline of the tooth at any other point, or at the ends of the jig, can be calculated in the same way, or after the outline is calculated for one point it can be determined for any other by bearing in mind the fact that all of the parts of the tooth at any other radius than B E will bear the same relationship to a tooth at that point that the new radius bears to B E. For instance, if the radius is 1¼ times

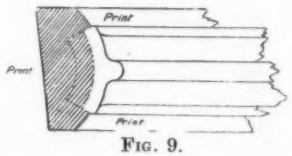


FIG. 9.

greater, all parts of the tooth would be increased 1¼ times, and so on.

In all calculations for the length of the back radius and the outline of the tooth at the ends of the jig, it should be borne in mind that the number of teeth in any given gear remains the same, no matter what radius is used.

When the drawing is completed, the block to form the jig can be accurately marked off, proceeding in a similar manner as in the case of the spur wheel.

Worm and Worm Gear Patterns.

In practice it is much easier to make the worm wheel suit the worm, so we will consider the pattern

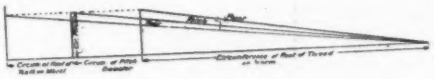


FIG. 10.

for a worm first. This pattern should be parted longitudinally so that two pieces of wood are required to be dowelled together and turned up to the outside diameter of the thread with the core prints attached. Do not destroy the centres used in the turning, as after the thread is cut the patterns can be returned to the lathe, when by using a slow speed the threads can be sand-papered. When the pattern has been turned to the proper diameter and length, wrap a piece of drawing paper around it and cut the exact length and circumference. Place the paper on a board and mark off spaces equal to the circular pitch, as shown in Fig. 8. If the worm is to be single-threaded, draw diagonal lines, as shown by the full lines. These will represent the pitch of the worm. If the worm is to be double-threaded, draw diagonal lines as represented by the dotted lines, each line rising two divisions. If it is to be a triple-threaded worm, then each diagonal line should rise three divisions, and so on for any number of threads, the angle increasing until the number of threads is so

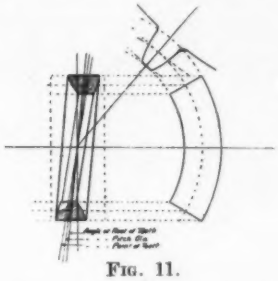


FIG. 11.

great and the angle so steep that it ceases to be called a worm, and is termed a spiral gear. If the worm is to be left-handed the diagonal lines on the paper would need to be the reverse to those shown in Fig. 8.

If the drawing has been done correctly, when the paper is returned to the pattern the point 1 will meet point 2, point 3 will meet point 4, point 5 will meet point 6, and so on, thus forming a continuous spiral line about the pattern. Now this paper can be gummed or glued to the pattern, and the worm cut

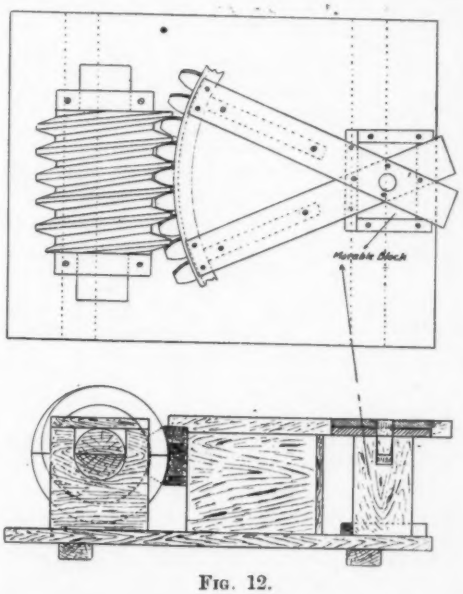


FIG. 12.

to the lines indicated, or with the aid of a sharp pointed instrument the outline of the thread could be pricked through the paper on to the pattern. The paper could be attached with a few spots of glue for the latter method.

The roughing out of the thread may be done by clamping strips of wood to the sides of a tenon saw, so as to give the desired depth, and then sawing

down on the lines already laid out. Or the outline may be formed by revolving the pattern in a V-block placed over the circular saw.

After the worm pattern is completed, the wood will be required for the worm wheel pattern. This pattern is simplified very much by making the teeth in

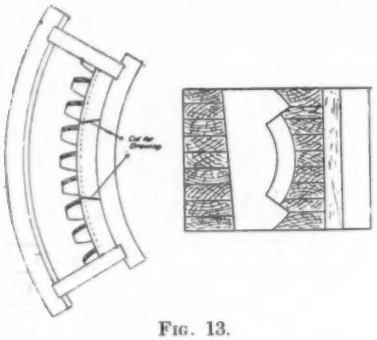


FIG. 13.

cores. For this reason the outer face of the pattern is turned up with a core print attached, having a good taper on the outside, as shown in Fig. 9. If the pattern were made complete it would be necessary to make the total number of teeth; while by

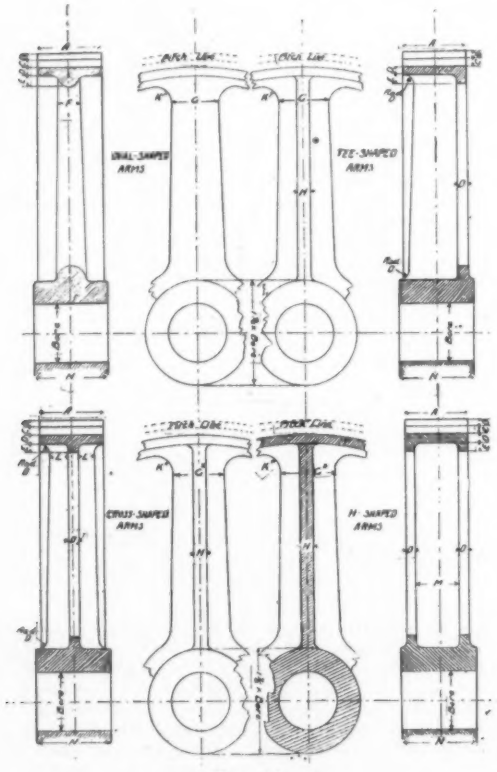


FIG. 14.

using a core box it is possible to manage without forming so many teeth, and thus reduce the time on the work. There is much difference of opinion as to the best way to make this pattern, but the following shows a method which has been successful. Mark out the angles corresponding to the root of the tooth, the pitch diameter and the point of the tooth, as in Fig. 10. This is done by developing the circumference of the worm at the root, pitch, diameter, and point of the thread, and erecting at one end of each a perpendicular equal to the given pitch. The lines connecting the top of these perpendiculars with the end of the lines representing the circumference will give angles as shown.

Fig. 11 shows the manner in which a block can be laid out and worked to the proper shape from the solid. The dotted lines show the outline of the block. This piece of wood should be so formed that it will fit the curve of the worm at the top of the tooth, and the curve of the face of the wheel at the bottom of the tooth. The outlines are marked off on both ends and connected as shown. It will be advisable to try the points of the teeth for clearance, as otherwise they may interfere when leaving the worm; for this purpose a jig can be arranged as shown in Fig. 12, whereby the segment of the core box having the teeth attached, may be mounted and revolved past the worm, the worm also being arranged to revolve by having grounds under the core prints. It is best

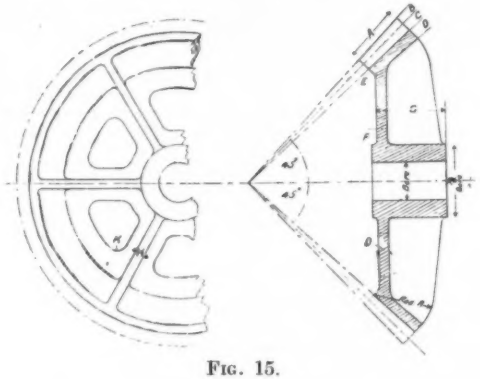


FIG. 15.

to set the wheel, or the segment of the wheel, so that it can be brought up to its correct position gradually, because invariably the teeth require to be dressed up. By coating the worm with a mixture of vermilion and methylated spirits, time will be saved in finding where the clearance on the teeth of the wheel is insufficient.

When the wheel is made to revolve past the worm satisfactorily, when set at their correct centres, a box can be made to enclose it, with which the correct sized cores will be made. Fig. 13, which represents the finished core box, requires no further explanation.

APPENDIX.

Tables suitable for standard spur wheels and also standard bevel wheels may be of service.

Standard Spur Wheels.

The number of arms depend upon the diameter of the wheels, and the style upon the particular class of work required by them, but the following can be used as a good standard: —

6 in. to 24 in. diameter	4 arms.
24 in. to 36 in. diameter	5 arms.
36 in. to 96 in. diameter	6 arms.
96 in. to 192 in. diameter	8 arms.

The above also applies to bevel wheels of all descriptions.

In Fig. 14 four styles of spur wheels are represented, and by turning to Table I. for letters corresponding to those on the drawings, the dimensions for any sized spur wheel may be found.

Standard Bevel Wheels.

Table II. gives the sizes for standard bevel wheels, which are indicated by the corresponding letters shown on Fig. 15.

TABLE I.

Pitch	A	B	C	D	E	F	G	G¹	G²	G³	H	K	L	M	N
1	2½	5/16	13/32	13/32	7/16	1 5/16	2¼	2¼	2 3/16	2⅜	5/16	7/16	5/16	1 5/16	3½
1¼	3	13/32	7/16	13/32	9/16	1½	2½	2 5/16	2⅝	2¾	13/32	9/16	11/32	1 11/16	3¾
1½	3½	15/32	1/2	15/32	11/16	1¾	2¾	2 15/16	2⅞	3	3/8	11/16	13/32	2 1/16	4½
1¾	4	1/2	9/16	17/32	3/4	1 7/8	3	3⅛	3 3/16	3¼	7/16	3/4	15/32	2 7/16	5
1⅞	4½	9/16	19/32	5/8	13/16	2 1/16	3¼	3⅜	3½	3⅝	1/2	13/16	1/2	3 1/16	5½
1⅞	5	5/8	21/32	11/16	7/8	2¼	3½	3⅝	3¾	4	9/16	7/8	1 1/16	3 5/16	6
1¾	5½	11/16	23/32	1	15/16	2⅜	3¾	4	4⅛	4¼	9/16	1	1½	3 15/16	7
1½	5½	11/16	23/32	1 1/32	2	4	4⅛	4⅜	4½	4½	5/8	1 1/16	1 5/16	3 15/16	7
2	6	3/4	25/32	1 3/32	1⅛	2¼	4¼	4⅝	4¾	4¾	3/4	1⅛	1⅜	4	7½
2¼	6½	13/16	27/32	1 5/32	1 5/16	2½	4½	4⅞	5⅛	5⅛	11/16	1¼	1 11/16	4 7/16	8
2¼	7	15/16	29/32	1 7/32	1½	2¾	4¾	5⅛	5⅜	5⅝	3/4	1⅜	1¾	4⅞	9
2¾	7½	15/16	31/32	1 9/32	1⅝	2⅞	5¼	5½	5¾	6¼	13/16	1 7/16	1 15/16	5 1/16	9½
2¾	8	1 1/32	1 1/16	1 5/16	1 11/16	3 1/16	5¾	6⅛	6½	6¾	7/8	1 1/2	2	5⅝	10
3	9	1 5/32	1 5/32	1 7/16	1 13/16	3 5/16	6⅝	6¾	6⅞	7⅛	15/16	1 11/16	2 1/16	6⅛	11
3¼	9½	1	1¼	1 15/16	1⅞	3½	7	7⅛	7¼	7⅝	1	1 13/16	2 1/8	6⅝	12
3½	10½	1 5/16	1⅜	1 13/16	2	3¾	7⅜	7¾	8 1/16	8½	1 1/16	1 15/16	2½	7⅛	13
3¾	11	1 11/32	1 13/32	1 15/16	2⅛	4	8	8⅛	8½	9	1¼	2⅛	2¾	7 7/16	14
4	12	1¼	1 5/16	1 15/16	2¼	4¼	8½	9	9½	9⅝	1 5/16	2¼	3	8⅛	15

TABLE II.

Pitch	1	1¼	1½	1¾	1¾	1⅞	1¾	1¾	2	2¼	2½	2⅝	2¾	3	3¼	3½	3¾	4
A	2½	3	3½	3½	4	4½	5	5½	5½	6	6½	7	7½	8½	9	10	10½	11
B	5/16	11/32	13/32	7/16	15/32	1/2	17/32	9/16	5/8	21/32	11/16	23/32	25/32	7/8	1	1 1/16	1 5/32	1¼
C	13/32	7/16	1/2	1/2	9/16	5/8	11/16	23/32	23/32	25/32	27/32	29/32	31/32	1 1/16	1 5/32	1¼	1 9/32	1½
D	13/32	15/32	17/32	11/16	23/32	25/32	27/32	29/32	31/32	1 1/32	1 1/16	1 7/32	1 5/16	1 7/16	1 9/16	1 11/16	1 13/16	1 15/16
E	3/8	3/8	7/16	7/16	1/2	1/2	9/16	9/16	5/8	5/8	11/16	3/4	13/16	7/8	1	1 1/16	1 1/8	1 3/16
F	3/8	7/16	1/2	1/2	9/16	5/8	11/16	11/16	3/4	3/4	13/16	7/8	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16
G	2¾	3½	4	4	4¾	5½	6	6½	6¾	7½	7¾	8½	9	10	10½	11½	12½	13
H	5/16	11/32	13/32	7/16	15/32	1/2	1/2	9/16	5/8	5/8	11/16	3/4	7/8	15/16	1	1 1/16	1 1/8	1 3/16
K	5/8	11/16	15/16	3/8	15/16	1	1	1 1/16	1 1/16	1 1/16	1 3/16	1 1/4	1 5/16	1 3/8	2	2 1/16	2 1/8	2 3/16

Slow Melting for Aluminium.

Commenting on the question of melting aluminium, "The Brass World" remarks as follows:—"We are convinced that the majority of aluminium founders melt their aluminium too rapidly. Aluminium melts at such a comparatively low temperature that there is always a tendency to allow the melting to take place rapidly, and with the result that portions of the metal are over-heated or burned before the remainder has become liquid. The final temperature, when all the aluminium has melted, may not be too high, but nevertheless, the overheating of a portion of the metal has resulted in injury. All metals are injured by overheating, and aluminium is affected by such treatment more than brass or bronze. The metal is oxidised and gas is absorbed, so that when castings are made pin-holes, blow-holes, and weakness result. The best method of melting aluminium is to allow melting to take place gradually, so that no portion is melted long before the rest has begun to heat. This can readily be accomplished by reducing the heat of the furnace, no matter what fuel is used. If foundrymen have blow-holes in their castings, and they are lacking strength, then the melting proposition should be looked to. It will usually be found that the cause of the difficulty is there. The ideal condition, although one rarely obtainable in practice, is when all of the aluminium (and this feature applies to other metals as well), begins to melt at the same time."

The Inspection of Castings.*

The Duties of the Inspector in the Grey Iron, Steel and Brass Foundry.

By J. A. Gearhart.

The inspection of castings, from the standpoint of the inspector, covers, in the main, just two conditions, good or bad castings. In other words, they are good enough for the service intended, or they are unfit for this service and should be rejected; but in the actual inspection of the work the inspector must be able to distinguish a real defect from a slight flaw, he must be able to decide whether a defect, when found, is of sufficient importance to affect the strength or wearing qualities of the casting, or if it is in a part not subject to strain in service and will, therefore, answer the purpose for which it was designed. He must know the exact location where the casting is to be used, what its functions are in service, and all other information it is possible for him to obtain. In checking to dimensions on prints he must know how close to drawing sizes the casting must be in the place for which it is designed, as it is well known that castings of the same design and made from the same pattern are not always exactly of the same measurements in all their dimensions, due to the variations in different heats or casts, as well as differences in the moulding and a dozen other variations too numerous to mention.

There are some dimensions where $\frac{1}{4}$ inch variation can be allowed, either above or below the given size, while on other dimensions $\frac{1}{16}$ inch allowance either way is too great; some surfaces must be straight and parallel with others so that clearances at other points may be maintained; while other surfaces must be at right angles so that certain points will have equal wear in service.

An inspector must know what pockets are to be cleaned, what corners are to be chipped square, in what corners a fillet can be allowed, and the largest radii permissible on any fillet. On castings of intricate design, where there are unequal shrinkages, he must know when the manufacturer has cast these with shrinkage brackets to overcome any checking. He must know whether it will be necessary to chip these brackets to the original contour, or if the shrinkage brackets may be left on and the castings accepted. The inspector must know, when he finds a shrinkage crack, if it is sufficient cause for rejection or if the casting is as good for the purpose intended as one on which no cracks appear. An experienced inspector will generally know, from the shape of the casting and the method of moulding, where the shrinkage cracks or blow-holes are most likely to occur. An inspector who knows where and how his castings will be used, will save considerable money for the foundryman, as well as time on the delivery of the work for his employer.

The Welding of Defects in Steel Castings.

At the present time, with the different welding appliances used so extensively in steel foundries, it is a question when the inspector finds a casting has been welded whether to accept or reject it, as he has no means of telling how serious the defect was before it was welded. The author knows of one concern that objected at one time to the welding of any part of its castings, and any castings showing the least indication of welding were rejected at once. So the foundrymen furnishing the castings did all the welding that they required before annealing, after which the surface was ground or chipped smooth and then thoroughly annealed. The castings, when offered to the inspector, were coated with a heavy scale. It was very difficult to tell in these cases if the castings were welded or not. Eventually it was specified that all castings to be welded must be first shown to the inspector, and now, if in his judgment the defect will not affect the strength or wearing qualities and the welding will improve the appearance, he stamps the casting with his private mark near the defect but not close enough to be obliterated in the welding. After the welding has been finished, the casting is again shown to the inspector, and if done in a workmanlike manner, is then accepted and restamped near the trade mark or pattern number.

Inspection of the Drawings.

It has been the author's experience that the best results have been obtained on orders subject to inspection, when the manufacturer and the inspector went over the drawings together so that important dimensions were fully understood and could be watched by the manufacturer in making the patterns as well as in moulding the casting. This plan, if followed, will generally save the foundryman considerable money as well as time in completing a contract. The author does not wish to convey the idea that the manufacturer should request the inspector to check patterns. The inspector should be glad of an opportunity to check sample castings, but never to check patterns, as he is not familiar with the shrinkages of the metal, nor the methods of moulding at any one plant, as he is interested only in the finished product.

Drawings and Specifications.

The drawings should be made to show clearly every detail necessary to guide the manufacturer in producing a casting, as well as for the information of the inspector. Often it is necessary to show the use of a particular part. In one instance, in making a type of cast-steel box from bolster, $\frac{3}{4}$-inch holes were shown. The inspector found the shop busy reaming these holes to an exact $\frac{3}{4}$ inch. They were drain holes only, and should have been so marked on the drawing.

When castings are made to specifications prescribing test pieces for physical tests, especially in cast steel work, the inspector should see that these test pieces represent truly the casting from which they were taken, and that they have not been given any additional treatment either by hammering, annealing or otherwise. It is common practice for most inspectors to have a hammer with a private mark for stamping test pieces and accepted castings, but the inspector should use judgment in the different shops, in the method of handling the test pieces after they have been selected and stamped.

Specifications covering steel castings, in all cases, require that test pieces must be cast on the castings and broken off in the presence of the inspector. It is important to know on what part of the casting and the manner in which this test piece is attached to the casting, so that the results obtained will fairly represent the material. The author has in mind castings weighing 15 tons each that had test pieces attached, made by the moulder pressing a round stick in the

* Abstract of Paper read at a recent meeting of the Pittsburg Foundrymen's Association.

bottom of the drag after the pattern was drawn and the mould ready to close. This stick was 1½ inches in diameter and was pressed about 4 inches in the sand at right angles to the casting, and no allowance was made for the gas to escape. The mould was gated at the bottom and the metal running over the bottom of the mould had pushed all the dirt and loose sand down these holes. Tests and analyses made from these pieces did not represent the material in the castings. Very few bars were found without flaws and other test pieces selected from the runner of the gate and from the castings taken with a hollow drill did not agree either in physical tests or chemical composition with the results obtained from the test pieces.

Blow-Holes.

The inspection of steel castings calls for the most careful work on the part of an inspector, as it is exceedingly difficult to distinguish between a mere blemish and a real defect. One casting will be spongy and porous on the surface, but all holes will be small and shallow, and will not affect its strength, while another casting will, to all appearances, have a smooth surface with the exception of a few small holes, which, when explored, will increase in width and volume with the depth, and the casting will be found to be only a shell.

The volume of area of blow-holes is often determined by the amount of water the cavity will hold. This test is an old one, and it would be well to caution the inspector before making the test to be certain that the cavity has not been filled previous to testing. A number of years ago a workman in a foundry, appreciating the prying curiosity of the inspector, filled the blow-holes with hot wax to nearly the top of the surface, and when tried with water, the inspector found only a shallow cavity. In another case a workman was found busily filling shrinkage cracks in the fillet of a large steel casting with a metallic substance, which was put in the crack in a soft condition. The crack was filled to the surface and burnt sand was rammed as a top dressing. The result was, indeed, a work of art. These methods and many others were used a number of years ago to have castings accepted by the inspector, but it has been found cheaper and better for all concerned to so improve shop methods that defective castings will be reduced to a minimum.

Inspecting Brass Castings.

When inspecting brass or bronze castings, aside from the tests and analyses specified, the inspector should break a few castings from each day's work. This will enable him to obtain an idea of the structure of the material, and it will give him an idea of how well the metals have been mixed. Any segregation, or soft and porous spots, will be detected, which is important in castings used for bearings, as any segregation generally develops a hard spot, while soft or porous spots act as a "catch-all" for dirt, causing unequal wear or hot journals.

On brass or bronze castings used for interior decorations it is necessary to pay particular attention to the colour of the metal so that it is uniform.

Inspection of Iron Castings.

On iron castings, particular attention must be paid to the thickness of sections. These are generally designed for a certain pressure, as pipe and pipe fittings, or to bear certain loads, as car wheels, etc. The thicknesses of sections and walls have been worked out when the castings were designed to give the desired strength with certain pressure or load. Any deviation in these thicknesses, especially on the low side, is apt to cause a failure in service, and is not what the purchaser pays for, nor has a reasonable right to expect. On a large casting, it is the best practice for the inspector to be at the foundry when the mould is closed and to witness the pouring.

A few years ago the author saw the base of a steam hammer that had broken in service. It weighed approximately 10 tons, and had been in use about four months. The failure was due to the fact that the centre of the mould had been filled with bolts, nuts, washers and other scrap, which had been anchored in the mould in some manner that held this material central while the mould was filled with molten iron. From outward appearances the casting was solid.

In the matter of tests, these are generally covered by the specifications, and it is the inspector's duty to know that the tests he selects are as nearly representative of the material in the castings as it is possible for him to obtain.

Inspector and Manufacturer.

There is no question but that it is the manufacturer's right to decide the manner in which the castings are to be made, but it is also the right of the inspector to examine the castings after they are finished, and it is his judgment that must decide whether they meet requirements, and are good enough for the purpose intended. By getting together before an order is commenced, or by making a few sample castings, much annoyance, for both the manufacturer and the inspector, can generally be avoided.

When the mixture has not been specified in the contract, the manufacturer has the right to decide the kind of material to use in making his steel, iron or bronze and the process of manufacture, but the inspector must decide whether the castings are of the grade of material desired, and if they meet the specifications under which they were purchased.

Working an Oxyacetylene Blowpipe.

When working an oxy-acetylene blowpipe for welding castings, quoted working pressures for oxygen should not be too rigidly adhered to. Even in the same sizes of blowpipes the conditions must vary slightly, and a little practical experience with each blowpipe will soon indicate the best working conditions. If the flame is not properly regulated it may fire back and go out. If so, the acetylene tap should be shut off at once, and a few seconds allowed to elapse before re-lighting.

When work is carried on for a long time at a stretch and the burner becomes warm, it will be found necessary to slightly open the acetylene supply taps from time to time. If work is being done which involves the nozzle of the blowpipe being held in a confined space, it is advantageous to cool this end of the blowpipe by immersing it from time to time in a bucket of water. When this is done the gases must be turned off.

Welding should be done at the apex or outer extremity of the small white cone. If the hole in the nozzle of the blowpipe gets obstructed at any time through beads of iron being splashed into it, or from any other cause, it should be cleaned with a wire brush. No rimer or other sharp instrument should be used in the hole.

On stopping work the acetylene taps should be closed first and then the oxygen tap. When work is completely stopped the oxygen cylinder should be shut off also, and the pressure released from the regulator.

Some Foundry Difficulties.

Practical Discussion by British Foundrymen.

There was a large attendance of members of the Birmingham Branch of the British Foundrymen's Association at a meeting held on Saturday, December 10, 1910, in the Municipal Technical School, when a discussion on "Foundry Difficulties" took place. The new departure proved a perfect success. Members had been invited to send in notes on difficulties in getting the requisite qualities in their castings, and from these queries the programme of the meeting had been made up. To open the discussion of each query a special speaker had been selected by the Committee. The following difficulties were discussed:—

(1) How to obtain a good surface on light castings, to obviate (*a*) streaks on surface, (*b*) rough surfaces, (*c*) kishy marks from runners, etc.

(2) How to prevent oven-plates splitting when in use.

(3) Segregation in bushes. Bushes 18 in. bore, 1 in. thick, 2 ft. long, when machined all over had brown spongy places in the bore.

(4) The cause of chilled rolls splitting after the chills have been removed.

Mr. H. L. Reason (Vice-President of the Branch) took the chair. Before the commencement of the discussion, six associate members and six associates were elected to the Association.

The CHAIRMAN briefly alluded to the subjects of discussion, and announced that as far as possible the questions on the agenda would be discussed separately and seriatim.

Mr. R. BUCHANAN, though he commenced by speaking on the first question, dealt more or less with all, as he was not able to remain long at the meeting. With regard to section (*a*) of question one, "Streaks on Surface," he said it was no unusual thing to find castings of a particular kind streaked more or less, some of them excessively so, especially if the castings were thin. He had come to the conclusion that it resulted from the closeness of sand combined with hard ramming. He had observed that if a man used red sand with a very small admixture of black amongst it, and especially if he had milled the sand, the streakiness was more in evidence. That led to the impression that it was something in the granular formation of the sand which caused the trouble, and that again led to the further conclusion that the trouble was really due to the fact that the air inside the mould could not escape rapidly enough. The streaks were really streaks of air which had become locked in the mould and had hindered the metal from getting into contact with the sand at those particular points where the lines were. He had proved that if a man hand-mixed his sand and refrained from ramming too hard the streaks were largely obviated. With regard to the question of roughness, he thought that the fault was very largely a matter of having the sand too wet. He had had such a case brought to his notice, and suggested that less water be put in the sand. The suggestion was adopted and the quality of the castings immediately improved. With regard to the question of castings being rough, he had partly answered that by telling the best way to make them smooth. As to the kishy marks from runners, etc., it was not a matter which he had observed himself. Possibly the gentleman who sent in this query might have had marks which he thought were kish, but which were something else. The runner on a casting such as was described in the drawing was usually wedge shaped, and the thin end of the wedge was on the casting itself. It was shaped in that way in order that the gate might break off cleanly and as little bobbing as possible should be required. He had a case in which they were constantly finding fine dust in the casting, and he finally discovered that a dusting-bag which contained a mixture of resin and powdered clinker was being used. Some of the dust which was shaken over run down the wedge and lay just along the junction of the gate. When the metal began to run in, it washed some of the dust into the casting. When this dust was blown off before pouring, the casting came out clear of dust. Therefore, he thought the gentleman who sent in that query must have seen particles of resin and thought he saw graphite, resin being, after all, a carbon. Further than that, he could throw no light on the question of graphite marks in the casting. If the marks were really graphite, then it must be that the longer continued heat of that part of the casting nearest the runner had allowed graphite to come out more than it did when the setting took place more rapidly. With regard to the cracking of rolls, it had not been explained whether the rolls were perfectly cool before the chills were taken off, but he took it that they were not cool. They had a chill of $\frac{1}{2}$ in. to $\frac{5}{8}$ in. in thickness, and this chilled outer portion was in the form of cementite. It was hard, but it was also brittle. This hard body was surrounding the casting, which was still in course of cooling, while the surface naturally was cooler than the inside. The surface was all in a state of tension; it was trying to contract while the warmer body inside had not started to contract. The outer portion, being a cooling body, and likewise a brittle body, was pulling with a tremendous force against a great central portion which was slower in cooling. That, in his opinion, was the solution of the problem of the cracking of chilled rolls—the immense tension of a hard body trying to contract upon a body which had not yet taken its full contraction. That was why they got the crack along the hard outside, and the natural corollary of that idea would be to slow down the cooling of the chilled roll, so that the tension of the outer skin might be reduced to a minimum.

Good Surface on Light Castings.

MR. R. MASON said that he had had a great deal of experience with light castings, and it would be hardly fair upon an occasion like that for him to keep silent upon a subject with which he was so well acquainted. He knew very well that in that district there were as good light castings made as anywhere, smooth castings which did not require to have anything done to them after being taken from the mould. He was referring to light castings of one-eighth inch to three-sixteenth inch in thickness, such as those for stoves, grates, ornaments, and similar things. The best and the only way to get good smooth castings was to have in the first place good smooth patterns. They could not make smooth castings otherwise. Then the patterns must be cleaned every time they were taken from the mould before being used for another mould. That was the most important part to begin with. The next was the material with which to face the castings. There were four sands with which he had had a good deal of

experience. French sand was very little used, but it was really the best sand for giving smooth castings. Unfortunately it was very expensive. It was only used at present for making very light castings, and very good results were got with it. But French sand, on account of its cost, might be left out of consideration at the moment. The next best sand he had used was Erith sand. This was very good, and was much used in Scotland, where a large number of light castings were made. It was used in Scotland mainly on account of its cheapness, as it was brought as ballast from London to the ports from which the castings were shipped. Another good sand was Mansfield sand. That was quite as good as Erith sand, and, as they all knew, it was red. Then there was the Stourbridge sand, the use of which often resulted in the streaks upon the surface to which the question referred—he had heard them called worm tracks, because the appearance was just as if a worm had travelled along and left its traces on the casting. To those who made light castings, this appearance was very familiar. He had had more trouble of this kind with Stourbridge sand than with any other. But all these three were good sands and, with proper care, good smooth castings could be got with any one of them.

The next most important point was the coal used. In making heavy castings it was the custom to use very coarse coal dust. For a light casting, the coal dust should be very much finer. In fact, it would be better to have a finer coal dust even for the heavier castings, but this was not done simply because the coarse kind went further. It was quite evident that when the coal dust was in invisible grains, as it were, it would not go so far as it would if insufficiently ground. The next thing was that the sand should be mixed in an efficient mixer; otherwise so good a job would not be made of the casting. Hand-mixed sand was often said to be the best. It was formerly mixed by hand regularly. It was ground in a pan-mill, and then further ground by hand with a roller on a board. Of course, it was always said that the smoothness of the casting depended upon the work done in that way, but he had not found that the case with Erith or with Mansfield sand. With Erith sand, treated in a mixer, he had obtained quite as good results as with milling and braying on a board. Some of them would remember on a recent visit to Coventry seeing a mixer at Messrs. Alfred Herbert's Edgwick Foundry. Having seen that mixer himself, he had every confidence in recommending it, though he had no connection with the makers at all.

As to the streaks along a plain casting, the marks were usually due to using too much new sand, and he had always so far been able so to spot this as the cause of the defect. He had repeatedly had to point out to his moulders that if they would only use a little more black sand in their mixture, they would avoid having these streaks, and he had noticed the same thing in other shops. Another point was using the sand dry. That was one of the things which a moulder nearly always overlooked, or, if he thought about it, was inclined to look the wrong way. He must admit that the majority of the moulders doing light work were not so highly skilled as were the majority of those doing heavy work, but the more skilled men had always realised that to get their castings smooth they must work their fixing sand as dry as possible, though to make the sand hold in the backs, the black sand required to be sufficiently damp to keep it together. But if the mould were examined closely, the facing sand would often be found damp—not really too damp to cast with, but with more moisture than was necessary to keep it close together, though, of course, if excessively damp, it would not lie so close together as if it were comparatively dry. The finished sand must be made as dry as possible, and the black sand a little damper to make up for this. When a man mixed the sand he worked it to have a fairly good grip, but when it was in the mould it was too wet. If the sand had been worked in a mixer it was found that it seemed to get damper. An examination of the mould would show the difference between the two sands, how close the mass seemed to lie in the drier fixing sand and how far apart the grains were in the damper sand. That at once explained why the castings came out rough. Of course, another point was that they must use a very fine sieve. The best results he had always got were with a sieve having ten openings to the inch length. An eight to the inch size was very much faster, but one could not get really smooth castings with a larger size than ten openings to the inch.

The next point was to ram the moulds fairly firm, but not too hard. The grains of the sand should never be rammed perfectly close. Of course, in light castings they were always tied in regard to weight; the inspector was instructed to see that the castings were not unnecessarily heavy, because that would be giving away metal, and to get the castings to the prescribed weight they had to ram well. That, of course, helped to give a smooth skin. Then, the metal must be poured at a suitable temperature, and that could only be judged by the moulder at his work. When the moulder had a big day's work to do he had not much time to wait for his metal to cool properly, and he was apt to pour at the highest temperature that would allow the casting to be passed by the inspector. Nowadays, moulds were not slicked all over with blacking. He remembered when patterns were turned out of the mould and brushed, and then blacking was shaken all over the mould and the pattern put back again. Nowadays, with new mixtures, they put very little blacking on. Regarding coal dust, it was best to have a buyer who would stick to one make. Once the right quality was obtained it was best to keep to the same manufacturer. As regards slicking with blacking, sand was now mixed so as to avoid the necessity for this. If the casting floor was not too hot, the blacking was not really necessary. Sometimes, it was found better to put a touch of blacking on at the runner, but it would come quite clear without any blacking if the fixing sand was properly mixed. Referring to the marks on the drawing shown in illustration of the question, he would suggest that the red sand should be reduced and more black used. Quoting from memory, he believed that to get smooth results they used three of black sand to one of red sand for castings of about ¼ in. to ⅜ in. thick. If the querist would use that proportion of black sand, or even more, he would not get those marks; and he must stop using his blacking. If the trouble were still experienced—though he (Mr. Mason) did not think that very likely—then a red sand from another pit should be tried. That might overcome the difficulty.

With regard to kish marks from runners, one mistake in the runner under consideration was that it was made the same thickness all the way. A break should be put in the middle of the runner, so as to make two sprays of it. By having one straight runner and the down-gate coming in front of it, these defects were liable to occur, but if a split were made where the down-gate came, that should prevent those dirty marks in front of the runner. If this did not prove sufficient, then less water should be used at the runner. He had been troubled with kish marks in front of the runner when using a certain iron. Sometimes, when the metal was becoming a little stiff, the kish could be seen right on the top of the ladle before the metal solidified at all, and they had difficulty in keeping it back from the pouring. Anyone who was using that kind of iron

entirely was likely to have kish marks. By kish he meant what in Scotland they used to call fossing, the carbon separating out on the top of the iron. The best way to get rid of kish was to use a harder iron with less silicon and less phosphorus. The answer to this query, therefore was: "Get a different scrap, and you will not be troubled with the kish." (Applause.)

MR. GRANT, having expressed general agreement with what had been said by the previous speakers, added that in his opinion wet runners were the cause of these marks. They were not kish marks, but sand marks, and were most pronounced when the molten metal was poured at a high temperature. When all other remedies failed let them try running the metal from the underside of the mould.

How to Prevent Oven Plates Splitting.

MR. ROBINSON, who was called upon to speak on the second question, "How to prevent oven-plates splitting when in use," asked for particulars of the case which had given rise to the query.

MR. CRAIG replied that the plate was 22 in. by 24 in., and 1⅛ in. thick. The casting was supplied to a cake-maker. It was all right when delivered, but the user stated that he had scarcely got his furnace lit when the plate cracked with a report like a cannon shot, and split a brick 9 in. away. The iron was a very good iron, with 2 per cent. silicon, 1 per cent. phosphorus, and 0.5 per cent. manganese. The user said he had just put the furnace on, and the plate was not even red-hot; he could put his bare hand on it.

MR. HEGGIE, after some further explanation, said: I should think that the plate was built in too tightly, so that no allowance was made for the expansion of the cast iron. There would be two expansions going on. While the plate was expanding there would also be an expansion of the brickwork, and this would cause an inward pressure while the iron was expanding outwards, and thus there would be a continual straining of the two materials one against the other. When the plate gave way suddenly, it was at the place where the expansion could go no further, and I suppose the brickwork gave way because it was not very strong.

MR. MASON: You would not expect a plate like that to break, but Mr. Craig cooled this plate under unusual conditions. It was not allowed to cool of its own accord. It is all right to help a plate to cool if you can regularly help it to cool, but you cannot. It was a mistake to cool it. I should say that the user applied his heat too locally, applied it to one point solely, and if he applied it at the point where the plate had been cooled too rapidly, then the sudden expansion would overcome the coherence of the casting, a coherence that was faulty owing to the too rapid cooling. I should say that if that plate had been heated up quite uniformly all over it would have stood the first heating, and if so, would have stood afterwards. But if heat is too quickly applied to any flat plate at one point, say in the middle, it is sure to go. A plate like that should be heated regularly all over the bottom surface. There is no doubt in my mind as to the cause of this plate splitting. It should not have been cooled when it came out of the mould; and when it was used the heat should have been applied regularly all over the bottom surface.

Segregation in Bushes.

MR. HOWELL was asked to open the discussion of Question No. 3, "The Cause of Segregation in Bushes." He said that the foundryman who had to produce castings for parts of machinery which had to be tooled all over and polished and must have good wearing properties, had a few more difficulties to cope with than the foundryman who had to produce castings, the skin of which was the first and only matter of importance. First and foremost among the many difficulties with the former class of work was that of porous parts which showed up during the machining, and which either gave trouble from the point of view of appearance or made the casting useless for any parts which had to withstand wear. This trouble they would probably have with them for all time, or at least as long as cast iron remained a complex, crude metal, such as they knew it to-day. But the foundryman frequently blamed the metal for porous parts in his casting, when he should look elsewhere for the seat of trouble. He was of the opinion that the trouble referred to in the question, concerning castings with brown spongy places, was not to be connected with the metal, but with other causes. A friend of his had a similar trouble with some tube castings which had to be machined all over. This gentleman had previously been making quite a number of these castings in loam, but in order to lessen the cost of production, decided to try to make them in sand. A pattern was produced and the moulds were made in a mixture of sand which had given good results in all his other dry-sand work. Three of the tube castings were made, and cast on three different days, and to all outward appearance were quite equal to any that had previously been made in loam. But when machined those castings were all porous in the bore, showing what looked like segregated places, with a brownish tint. Upon examining one of these castings, he (Mr. Howell) found that the surface was quite spiky, not a rough surface, for the castings were pleasing enough to look upon, but needle-pointed at intervals all over. This was not easy to be seen, but quite perceptible to the touch, and the other two bad castings were exactly similar. On further looking into the matter, he was convinced that it was the sand and not the iron that was causing the trouble. The iron used for these castings was a hard semi-steel mixture cast at a high temperature and run into the mould as fast as possible. His contention was that the sand was not strong enough to withstand the searching influence of the molten metal when filling the mould. The iron had eaten its way into the sand, owing to the mould not being tough enough, causing tiny particles to break away from the side of the mould, and this was the cause of the spiky surface that could be felt on the sides of the castings. These tiny particles so broken away would be carried on the surface of the metal in the form of dust or scum, and when any quantity had accumulated would be trapped by coming in contact either with the surface of the mould or with the core, and would thus be shown up when machining. This, however, would not be a porous part as generally understood, or any other imperfection of the metal, but a dirty part caused by those particles of sand in the form of dust being mixed up with the iron. The remedy was then tried of making the sand much stronger, using 90 per cent. of new sand and 10 per cent. of old ground together and with no coal dust. This proved to be entirely successful, and all the castings since made had given equally as good results as when made in loam. He felt confident from this experiment and after several months of experiment on similar lines, that if foundrymen would give the sand question closer study and consideration there would be considerably less need of blaming the iron for porous castings.

Kishy Marks from Runners.

MR. PEMBERTON (Derby), referring to this question, said that the splitting up of the runner so far as to make several sprays would obviate kishing. He

did not believe that it was altogether the resin, as Mr. Buchanan had suggested. He thought it was due to the runner cooling a long while after the casting had cooled, because if they had the down-gate on the top of the runner, the runner at the base was, as a rule, thicker than the casting. (He was speaking, of course, of thin castings.) In such a case, they must expect to find worm marks and also kishing in the runner. He thought that the worm marks were due in a great measure to the ramming of the mould too hard, and the insufficient venting—if any venting were done. He knew that in many cases, with small thin work, they did not vent, as they used a somewhat open sand. But the sand must be ground, and ground up with old sand, and not so much new sand should be used.

General Discussion.

MR. PEMBERTON, continuing, said that in the third question segregation in bushes was referred to. It appeared to him that the bush in question was a similar thing to what was made for cutting piston rings from. Upon such a bush they had to have lugs by which it was held on the machine for turning. He had had some experience with this work, and he had found that the segregation took place from underneath the lugs. He found that running a bush of this description at the bottom gave the best results. Even then—and whether they made the bushes in green sand or in dry sand moulds—they did not get over the difficulty of segregation, but it was never found until the bush came to be turned, and it was hardly ever found with a very light bush. If they were taking $\frac{1}{8}$ in. off the skin they would hardly discern it, but if $\frac{3}{32}$ in. were taken off they began to perceive the dark patch. No doubt, it would be said that there was too much graphite, but if they altered their mixture on that supposition, they would have trouble in the machine shop. That certainly was not always the case, and he thought the difficulty would always come in if they ran in the lug at the top. To obviate that difficulty, he recommended a mixture which could be easily made up from the specifications of their pig-iron, namely, graphitic carbon 2.7 per cent.; combined carbon, 0.5 per cent.; silicon, 1.8 per cent. (which was not up to what might be called the average, but a little lower); sulphur, 0.04 per cent.; and manganese, 0.75 per cent. The phosphorus could be carried to 1.25 per cent., and on using a mixture with that analysis for casting bushes of this description he did not think they would get the segregation. He had found by experience that with this particular thing it was only by increasing the manganese they could get over the difficulty. By lowering the silicon, although it looked wrong, they found they got excellent results with regard to avoiding the segregation of bushes. When using this mixture they got no spongy places, or scarcely any at all. He would like to ask Mr. Mason if he would give them his mixture of facing sand for light castings.

MR. HAILSTONE: I think Mr. Pemberton and Mr. Howell have been talking about two different things. Mr. Howell was talking about a hole in the casting filled with a spongy mass, whilst Mr. Pemberton was talking about the ordinary drawing from the lug, the bright hole in the casting.

MR. PEMBERTON: It does not show a hole in the casting at all. It shows brown, something more of a spongy kind. It is the usual kind of sponginess, and does not show any hole at all. It is a kind of perforation. Under the microscope it is found to be segregation in the bush. It is not one particular hole, but a kind of dappled surface.

MR. HOWELL: I think if Mr. Pemberton would extend his pattern so as to be able to throw away the scrap part, he could overcome the difficulty quite easily.

MR. HAILSTONE: Two persons will talk of sponginess with two different meanings. I should think Mr. Howell's case is not one of manganese sulphide, because the iron he had talked about shows much more sulphur than manganese. The manganese sulphide in the casting, when the pouring has been at a very high temperature, has had time to rise to the top of the mould and there segregate.

MR. HOWELL: I fail to see how it is possible to reconcile that with the fact that this particular mixture has been used for extended periods with excellent results, and this difficulty had not been met with until the change of methods. Then, when that method was improved upon, the difficulty was overcome without any change in the mixture. The only change that had taken place was in the first place going from the strong loam sand to a weaker sand that had given good results in other cases; then, making that sand a little stronger by degrees, we used the mixture in the same way, and having arrived at a happy mean, we got good results with it.

MR. HAILSTONE: I think Mr. Howell has answered the question himself. When using the strong sand, the iron is much more under pressure. On cooling, if you have strong pressure, you do not get anything like so much segregation. The looser the sand the more segregation, and the harder the sand the less segregation.

MR. MASON: This word segregation is to many of us rather to big a one. A large number of us do not know what it means. If we had said "shrinkage marks" it would have been understood more clearly by the majority. I think segregation is very much mixed up with shrinkage marks. By shrinkage is meant something different altogether from contraction. By shrinkage, we mean an alteration in the casting while it is still in the plastic or fluid state. By contraction, we mean what occurs in the solid state, the alteration in the length of the casting after it has solidified. I think Mr. Howell has treated this subject very well, and I do not think there is any necessity to go any further with it. He found he had trouble in getting a certain class of casting and he has told us how he found the remedy.

In castings run from different points, even if they are of the same thickness throughout, there will be different points of solidification. One part will solidify before another, and when that happens there is a contraction of the last part of the metal to solidify. Mr. Hiorns calls it the mother-liquor; that is, when it begins to solidify there is one component of the metal of a higher solidifying point as compared with that of the rest. As the metal cools, the other part of the metal rejects that part and pushes it further along, so that it gradually accumulates at this last point of solidifying. That is how this segregation is got. Mr. Pemberton, when he uses manganese, does so to overcome that shrinkage of the metal by making it solidify more quickly.

I have been asked to give the mixture for the fixing sand for light castings of, say, $\frac{1}{4}$ in. thickness. By weight we use 67.2 per cent. of black sand, 29.2 per cent. of new sand, and 3.6 per cent. of coal dust. In cubic inches, in which it is our usual custom to measure, this works out as follows:—69.5 cubic inches of black sand, 23.2 cubic inches of new sand, and 7.3 cubic inches of coal dust; or by rough measure, 10 buckets of black sand, 3 buckets of new sand and 1 bucket of coal dust. I would use the same amount of new sand whichever sand was chosen—Erith, Mansfield, or Stourbridge.

The Production of Castings to withstand High Pressures.*

By Professor H. C. H. Carpenter † and Mr. C. A. Edwards. ‡

This Paper contains on account of an investigation undertaken by the authors three years ago, with the encouragement and financial support of the Council of the Institution of Mechanical Engineers. The object of the investigation was the production of castings of non-ferrous alloys capable of withstanding high pressures, whether hydraulic, steam, or gaseous.

The Paper opens with a résumé of the principal materials used in present-day practice, and the difficulties encountered in producing sound castings of the non-ferrous alloys, which difficulties may be summarised under three main heads:—

(1) Those liable to be caused by the metal or alloy:—

(*a*) *Dross* or *Scum*, due to oxidation.

(*b*) *Piping*, due to the shrinkage of the fluid metal.

(*c*) *Pinholes* or *Sponginess*, due to the trapping of gas set free on solidification among the crystals.

(*d*) *Heterogeneity*, due to the segregation, under certain conditions, of particular constituents and resulting in brittle and sometimes unsound patches in the alloy.

(*e*) *Stresses*, set up in the solid alloy by the unequal contraction of its structural constituents, sometimes leading to microscopic fractures.

(*f*) *Deterioration*, due to structural or molecular changes in the alloy with lapse of time, leading to the so-called "crystallisation" of the material, and resultant weakness.

(2) Those liable to be caused by the pattern:—

(*g*) *Stresses*, set up during cooling by abrupt changes in thickness of section, for example, at the junction of flange and body.

(*h*) *Planes of Weakness*, if not actual fracture, caused by the crystals growing in a particular direction, for example, in rectangular castings.

(3) Those liable to be caused by the mould:—

(*i*) *Blow-holes*, due to the mould being too hard, or too damp, or to the sand containing rust or scale.

As a result of this analysis of the difficulties surrounding the problem, the authors decided upon a line of attack which may be defined in the following general terms:—To start with the simplest case possible, and to work out the conditions for success, bearing in mind the limitations imposed by practice. Having achieved this, to introduce one variable or complication at a time, and to work out the conditions for its success, before proceeding to the next, with the object of finally including all these in an ordinary industrial case.

Experimental Arrangements.

The entire work has been done at the University of Manchester. The alloys were cast in the metallurgical department. They were melted in crucibles in an oil-injector furnace, which permitted the handling of ½-cwt. charges. The castings were then machined, and if they appeared to be clean and sound, the valve was fitted into them. In the earlier experiments the valve was made of the same alloy as the casting. Inconvenience, however, arose from the fact that sometimes the valve failed before the casting. Accordingly a mild-steel valve was used in all the subsequent tests. This valve was coned at one end, and in making the joint it was pulled down so as to "bite" into a flat surface machined in the casting. The arrangement is shown in Fig. 2. The casting was first tested on a pump made of a special bronze and fitted with four valves, two automatic and two screw-down. The pressure was taken up to four tons, and if the casting held this without the least sign of leakage for 24 hours, it was considered to have passed the preliminary test. It was then tested on a high-pressure hydraulic pump, designed by Professor J. E. Petavel, which permitted of the pressure being raised to 20 tons.

The following are the requirements of the castings whose production was contemplated:—(1) Mechanical strength, including sufficient rigidity and ductility; (2) homogeneity; (3) soundness; (4) freedom from liability to deterioration; (5) minimum corrodibility in fresh and sea water.

FIG. 1.—CHILL MOULD USED TO CAST EXPERIMENTAL CYLINDERS.

First Experiments; The Casting of Cylinders.

The authors chose as the simplest case possible the casting of a cylinder in a chill mould. By doing this they reduced to a minimum the chance of encountering difficulties caused by the mould and the pattern, and were able to concentrate on the selection of a suitable alloy, and the working out of the conditions of casting it. The mould specially designed for the purpose is shown in Fig. 1. It was made of grey cast-iron. The part occupied by the metal is painted white, and shows the gate terminating in a small well which leads to the casting proper. The latter is surmounted by a riser. The cylinder was 6 in. by 2½ in. After cutting off the gate and riser, it was machined to 5¾ in. by 2¼ in., and was then bored in the manner shown in Fig. 2, the bore and thickness of wall each being ¾ in. The use of a chill mould not only reduces to a minimum the liability to blow-holes, but also to pinholes or sponginess. Rapid cooling is one of the chief aids to the escape of gas. By causing molecular contraction, it prevents the inclusion of gas bubbles between adjacent crystals and assists in expelling them through the still liquid interior. Thence they rise through the central portions of the ingot, and are enabled to escape into the air. The difficulties tabulated under 1 (*a*), (*b*),

* Abstract of Paper read, December 16, before the Institution of Mechanical Engineers.

† Professor of Metallurgy, Victoria University, Manchester.

‡ Research Fellow and Demonstrator, Victoria University, Manchester.

and (*e*) would no doubt be removed—certainly they would be minimised—if the alloy could be melted and cast in a vacuum. But so far as practical conditions are concerned, this is a counsel of perfection. The melting and casting have to be done in air. The remaining difficulties, 1 (*d*), (*e*), and (*f*) are bound up with the composition of the alloy, and are not due, like (*a*), (*b*), and (*c*), to its contamination by external agents. In the authors' view it is the choice of a suitable material which constitutes the most difficult aspect of the problem. This was accordingly made the first point of attack.

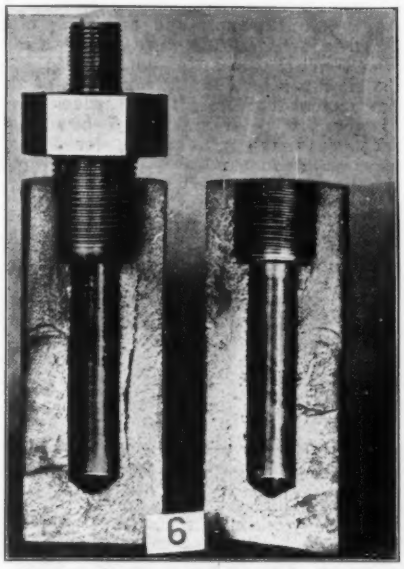


FIG. 2.—SHOWING SPLITTING OF CYLINDER, NO. 6.

At the outset, experiments were made with a pure gunmetal containing only copper and tin, in the proportions of 85 to 15. Owing to the inappreciable volatility of these metals under the conditions of melting and casting, it was easy to make any alloy of this composition, and to repeat it as often as was required. In this respect it presented advantages over the complex gunmetals and still more complex manganese-bronzes. Metals of the highest *commercial* purity were used—electrolytic copper and "Straits" tin, containing 99.98 per cent. of the respective metals. The copper was melted under wood charcoal in a covered crucible. After the addition of tin, sufficient phosphorus, in the form of a copper phosphide containing about 15 per cent. of phosphorus, was added so as to remove oxygen and leave not more than 0.1 per cent. of phosphorus in the cast alloy. After stirring well and skimming the metal was poured. It was, of course, cast from the bottom. Under these conditions the authors were able repeatedly to produce castings which were perfectly sound and after machining withstood pressures of, on an average, 18 tons before they burst. Previous to fracture there were so signs of leaking. So far as chill casts are concerned, this pure gunmetal alloy, *when freshly cast*, gave quite satisfactory results, though it showed itself to be a somewhat brittle material.

The next step consisted in casting the same cylinders in sand moulds. These were cast from the bottom and were supplied with a large riser. Both green and dry sands were used. The castings made in this way were not very satisfactory, and experiments in this direction were not pushed further because the authors learnt that gunmetals of this composition deteriorate with lapse of time. Frequently an initially sound casting becomes leaky after a year or so.

Experiments with the Aluminium-Bronzes.

Experiments with the aluminium-bronzes were next taken up. From their experience gained in preparing the Eighth Alloys Research Report to this Institution, the authors considered that certain of these might prove to be suitable materials. The following table is taken from page 114 of that Report:—

Sand Castings.

Aluminium.	Approximate Yield-Stress.	Ultimate Stress.	Elongation on 2 inches.
Per cent.	Tons per sq. in.	Tons per sq. in.	Per cent.
7.35	6.6	21.30	71 0
8.12	7 7	24.91	58.0
8.67	9.8	28.1	48.0
9.38	9.7	30.38	36.2
9.90	11 3	31.70	21.7
10.78	14.1	29.52	9.0

These alloys appeared to have the following advantages:—

(1) Their freezing interval is so small that there is no segregation, even if they be cast in sand. They are very homogeneous alloys.

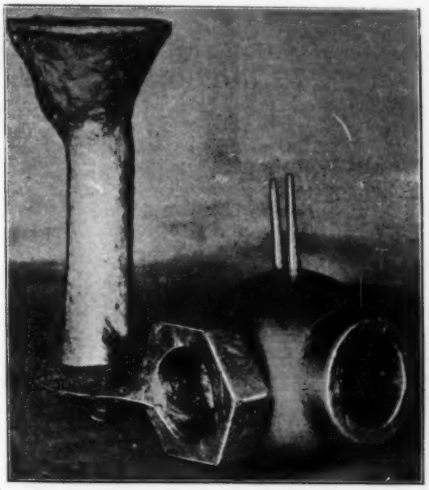


FIG 3.—HIGH-PRESSURE STEAM FITTING OR VALVE, AS CAST; TESTED TO 1.5 TONS HYDRAULIC, AND 180 LBS. STEAM PER SQ. INCH.

(2) They possess considerable tenacity and ductility, the former rising and the latter falling as the aluminium is increased. Thus they offered a variety of materials, in the earlier members of which, moderate strength, combined with great ductility, were the principal features, whereas in the latter, considerable strength and sufficient ductility were united. It was argued that if a particular alloy were not sufficiently rigid it could be stiffened by a slight addition of aluminium, whereas if it were too hard it could be rendered more ductile by raising the percentage of copper.

(3) It is quite easy to prepare an alloy of any of these compositions.

(4) Their corrodibility, either by fresh or sea water, is known to be slight.

The first aluminium-bronzes made were cast in the chill mould already described. In order to reduce the cost of the experiments, the authors' practice throughout their investigation has usually been to make 4 to 6 casts at a time of any given alloy, thus enabling them to be machined together. The first mixtures contained 91 per cent. of copper and the remainder aluminium. (The purity of the latter was 99.53 per cent.) They were prepared by melting the copper in a covered crucible and adding the aluminium to the fluid copper. A considerable amount of dross formed under these conditions. It was removed as far as possible by stirring and skimming. The temperature of the melt was taken in the crucible by a thermo-junction and direct-reading pyrometer. Each mixture was poured at 1,125 degrees C., which is about 80 degrees above its freezing point. This 9 per cent aluminium-bronze thus proved itself capable of holding the same high pressures as the 15 per cent. gunmetal, with the difference that it showed greater ductility. Six casts of the same composition were then made in green-sand moulds. The metal was poured from the bottom and a large riser used. Three castings did not even pass the preliminary test. The remaining three appeared satisfactory and were then tested under higher pressures. These tests showed that it is possible to cast cylinders of aluminium-bronze, both in chill and sand moulds, which are not burst by water-pressures of 18 tons per square inch. Their only drawback was that they began stretching at pressures of 10 to 12 tons, the sand castings giving the lower figure, as might have been expected. These results were encouraging in spite of the fact that, although the sand castings had apparently been produced under the same conditions, only three out of six were sound. Accordingly it was decided to experiment with a stiffer material by raising the aluminium percentage in the bronze.

The following table summarises the results obtained with bronzes cast in green sand, and containing between 9 and 11.5 per cent. of aluminium:—

Aluminium.	Gauge pressure at which the valve-joint began to leak.	Maximum pressure to which the casting was subjected.	Wall-thickness of cylinder under test.
Per cent.	Tons per sq. in.	Tons per sq. in.	Inch.
9.0	10	19	¼ cylinder unbroken
9.5	11	15	¾ " "
10.0	12.5	18	¾ " "
10.5	14	18	¾ cylinder burst
11.0	no leak	20	¾ " "
11.5	no leak	15	¾ " "

The gradual "stiffening" of the castings by increasing the aluminium is well brought out. Up to 10 per cent of this element, it is practically impossible to burst a sound casting by hydraulic pressure owing to the gradual stretch of the material. The most serviceable bronzes under this test are those containing from 10.5 to 11 per cent. of aluminium. They are stiff and tough alloys, and break with considerable extension. The 11.5 per cent. bronze is a brittle material, markedly inferior to these.

Four more castings of the 11 per cent. bronze were made under the same conditions. One of these failed to pass the preliminary test. Its unsoundness appeared to be caused by dross. The other three held water-pressures up to 19 tons. They were machined down to ¾ in. wall-thickness. On re-testing they stood up to 18 tons without leaking, and then burst.

The investigation had now been advanced to the stage that cylinders of aluminium-bronzes could be cast in ordinary green-sand moulds, which, except for an occasional failure, were capable of holding hydraulic pressures of 15 to 20 tons. By varying the exact percentage of aluminium, considerable latitude as regards ductility and strength had been obtained. Alloys of suitable composition thus appeared to have been found.

Experiments with a Hydraulic Valve-Block.

The next step was to produce castings of these bronzes in more complicated forms. The type chosen was a hydraulic valve-block, such as is used in high-pressure hydraulic pumps, and consisting of a lug, barrel, and base-plate. The valve-block was cast with a riser on the lug, such as is shown on Fig. 4, except that the riser was smaller. The position of the gate was also somewhat different. The general arrangement, however, was similar. Fig. 5 shows the valve-block after it has been machined for testing. Its dimensions are as follows—

Lug.—Diameter 2½ inches. Height 2 inches.
Barrel.—Length 8½ inches. Diameter 2½ inches at wide end; 2 inches at narrow end.
Base-plate.—5½ by 4 by ¾ inches.

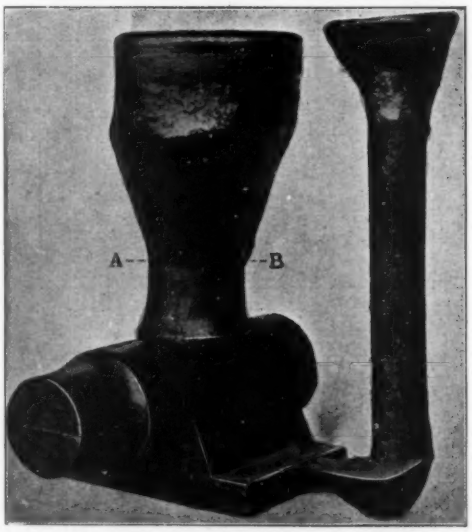


FIG. 4.—¾-INCH. HYDRAULIC VALVE-BLOCK, COMPLETE WITH GATE AND RISER.

Two valve-blocks of the 11 per cent. bronze were cast. Neither of them was successful, although the metal was clean and precautions were taken to keep a good head of fluid metal during the solidification. On cutting off the riser it was found that a number of draws were present, distributed radially across the lug. These might have been caused either by the trapping of gas bubbles set free during the freezing of the metal and their being drawn out as the crystals grew, or by a difference in the coefficient of contraction of the two structural constituents of the alloy. Two casts of the valve-block in the 10.5 per cent. bronze were then made. These were also unsound, but the faults appeared to be due not to draws but to dross, which crept through the skim-gate and was deposited on the near side of the barrel.

With a view to simplifying the problem, the base-plate was removed, and only the barrel and lug cast. (Machined specimens are shown in Fig. 6.) Five such castings were made in the 10.5 bronze. Only one of

them stood the high-pressure hydraulic test (15 tons). Even this was not quite free from dross. The others were all more or less contaminated in this way, even though various methods of trapping it were used. Two of the castings showed sponginess in the lug, and one of these showed piping as well. The authors' first attempts were directed to the problem of obtaining clean metal, leaving the piping and sponginess for later work.

Experiments were made to clean the fluid metal by the addition of certain deoxidizing agents and fluxes. The addition of 0.5 per cent. of magnesium gave alloys that were too brittle, and, accordingly, the use of magnesium was discontinued. Calcium silicide did not react in any way with the alloy. Sodium carbonate was tried in the hope that the alumina would slag off as sodium aluminate, and clear the dross from the metal, but this hope was not realised. A mixture of sodium carbonate and borax gave a more fluid slag, but dross formed on the upper surface of the casting in the same way as before. With the addition of 0.5 per cent. of manganese, the same accumulation of dross on the upper surface of the casting was obtained. After machining, the lug leaked at 1.5 tons pressure.

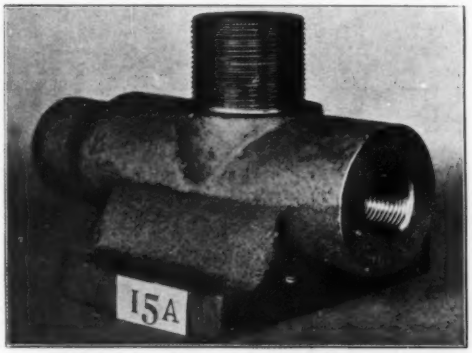


FIG. 5.—¾-INCH HYDRAULIC VALVE-BLOCK, MACHINED FOR TESTING.

Finally, a copper-tin-aluminium bronze of the following composition was cast:—Copper, 88 per cent.; tin, 6 per cent.; aluminium, 6 per cent. This alloy poured much better, and the upper surface of the casting was quite clean. Even after machining it looked perfectly sound. Under the water test it failed completely. In spite of the fact that the experiments just recorded all failed to give satisfactory castings, they were productive of valuable information as to how the dross gets into the finished castings. This information may be condensed into the following summary:—

The pure aluminium-bronzes were very viscous in the liquid state, even at the highest temperatures. They pour "thick" and "sluggish." This sluggishness is not directly due to the metal itself, but to a tenacious film of alumina, that is, oxide of aluminium, which invariably covers the surface of the alloy. This can be demonstrated by giving a crucible full of the alloy a rotary movement with a stirrer and noting the surface. It will be seen that the surface film quietly comes to rest whilst the metal immediately below is still moving rapidly. Accordingly it may be concluded—and it is a deduction with the authors' later work supports—that the liquid metal does not offer any unusual resistance to the natural tendency of the dross to rise to the surface. Consequently, as in all cases, particular care was taken to have the metal perfectly clean before pouring; the authors were convinced that the dross was in some way formed inside the mould.

By using a large riser on the lug, it was possible to see the metal enter and gradually fill the mould. The metal entering the mould through the well at the bottom of the gate was quite clean. On this metal a skin of alumina formed at once. If, as in the authors' earlier experiments, the metal enters quickly, ripples or waves are formed which break through this skin and expose fresh surfaces of clean metal, which are immediately oxidized. The perpetual recurrence of this process causes the formation of a large amount of dross. This is not carried out of the mould through the riser. The moment it comes in contact with the sides of the mould it sticks. This is why it is present in the castings, and particularly in the upper part. Thus any factor which produces ripples or any other kind of agitation of the metal, causes a much larger surface to be exposed, and so more alumina is formed. This skin of alumina is tenacious and very refractory. Consequently, when two or more ripples overlap, the skin prevents the metal from uniting. This explains why such a large amount of dross forms when aluminium-bronzes are stirred.

It follows from the foregoing that the aluminium-bronzes should be poured as quietly as possible, and every care should be taken to prevent the metal being agitated after it has entered the mould. All subsequent casts of these bronzes have been made in accordance with these principles, and all difficulties

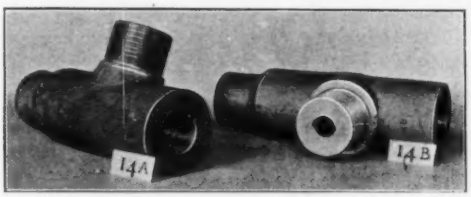


FIG. 6.—¾-INCH HYDRAULIC VALVE-BLOCKS WITHOUT BASE-PLATE, MACHINED FOR TESTING.

caused by dross have disappeared. With care, and a little practice, castings can be made with regularity that are absolutely free from dross, if the following precautions are adopted:—

(1) The metal should be poured very slowly.
(2) The gate should be so arranged that the metal enters the mould at the lowest possible point. Broadly speaking, any form of gate will do, but the authors' conclusion is that it is decidedly advantageous to provide a sort of well at the bottom, and use rather a narrow opening. (See Fig. 4.)
(3) In the case of green-sand moulds, wet sand must be guarded against, particularly in the lower parts of the mould where the metal rests on the sand. If a rather close sand is used it is far safer to dry the surface of the lower part of the mould.

Under these conditions the metal enters the mould quietly. As it spreads out the skin of alumina is stretched and broken, and fresh alumina is formed until, as in the castings under consideration, the full length of the barrel is occupied. As the metal rises, this skin is not broken but is pushed up until it reaches the upper surface of the mould. After this the metal mounts the riser, pushing the skin until the riser is filled. The final result is a casting with a thin and approximately uniform skin of alumina containing perfectly clean metal inside.

Hydraulic Valve-Blocks without the Base-Plate.

Adopting the above precautions, the authors cast four of these with the 10.5 per cent. bronze and seven with the 10 per cent. bronze. These were, without exception, free from dross. Two machined specimens, 14A and 14B, ready for testing, are shown in Fig. 6. (The diameter of the bore in the lug and barrel is $\frac{3}{4}$ in.) The following table summarises the results of the tests:—

Alloy No.	Aluminium	Gauge Pressure at which the valve-joint began to leak.	Maximum Pressure to which the casting was subjected.	Remarks.
	Per cent.	Tons per sq.in.	Tons per sq.in.	
14 A	10.5	14.0	18.0	Sound casting
14 B,C,&D*	10.5	—	—	Spongy ,,
14 E	10.0	—	—	,, ,,
14 F	10.0	12.0	15.0	Sound ,,
14 G	10.0	14.0	18.5	,, ,,
14 H	10.0	12.5	15.0	,, ,,
14 I	10.0	13.0	15.0	,, ,,
14 K	10.0	13.5	15.0	,, ,,
14 L	10.0	12.5	15.0	,, ,,

* These alloys contained manganese in proportions varying between 0.2 and 0.5 per cent.

Seven out of the eleven castings were satisfactory. They did not stretch until pressures of from 12 to 14 tons had been reached. All of these were tested up to 15 tons and two of them up to 18 tons. Owing to the ductility of these bronzes the labour involved in fracturing them under this test would have been excessive. It was not attempted, particularly as the authors had reason for thinking that the pump was likely to fail first. The tests given are quite sufficient to demonstrate the capabilities of the bronzes, and are severer than are likely to be realised in practice.

Three of the four bronzes which failed contained (intentionally) small amounts of manganese, the object being to see whether the radial slits that are sometimes found in the riser and lug could be prevented. These castings were all spongy, and two of them were piped in the lug. Manganese really accentuates this difficulty instead of removing it.

In this type of casting the best results were obtained with the 10 per cent. bronze, whereas the original cylinder could be satisfactorily cast in the 11 per cent. bronze. These bronzes consist of mixtures of two constituents at ordinary temperatures, namely, α' and β. The latter is the compound Cu_3Al; the former is either a solid solution of aluminium in copper, or a compound Cu_4Al. Its composition varies somewhat with the rate of cooling, the two constituents being soluble in one another at temperatures above 530 degrees C. (954 degrees F.). These constituents doubtless possess different coefficients of contraction. In small castings which cool relatively quickly, there is a less perfect separation of the constituents, corresponding to equilibrium at any particular temperature, than in large castings. Consequently the differences of contraction are more marked the larger the casting, and there will be a greater liability to contraction stresses, which cause weakness and in extreme cases unsoundness. This is the probable explanation of the difference noted above. In still larger castings the authors have found it advantageous to diminish the aluminium to 9.75-9.5 per cent. for the same reason.

Microscopical examination has shown that the structural constituents of a given aluminium-bronze are similar, no matter whether the casting is large or small within the limits examined by the authors. The structures of the large castings are naturally somewhat coarser, but not very markedly so. They appear, however, just as homogeneous as the small castings. This is a most important property of these bronzes.

Hydraulic Valve-Blocks with Base-Plate.

The same general principles were followed in casting the complete block. Preliminary experiments were needed to show the most suitable form of gate and well, and a larger riser was used. It was found advantageous to face the mould with a somewhat coarser sand. On account of the base-plate exposing a large surface to the bottom of the mould, it was more than ever necessary to dry the latter to ensure that the metal lay quietly on it. Fig. 4 shows the arrangement finally adopted, and gives the complete casting, which weighs about 26 lbs. Fig. 5 shows the valve-block machined and ready for testing (15A), which weighs 14 lbs.

In the earlier experiments 10 per cent. bronzes were cast. Some of these exhibited a tendency to sponginess, chiefly in the lug; others were quite sound, and gave satisfactory tests. The later mixtures contained either 9.75 or 9.5 per cent. aluminium. Most of these were satisfactory, and the following table, based on 15 tests, summarises their properties under the hydraulic test:—

Aluminium	Gauge Pressure at which valve-joint began to leak.	Maximum Pressure to which the casting was subjected.
Per cent.	Tons per square inch.	Tons per square inch.
10.0	11-12	17
9.75	10-11	15
9.5	9-10	14

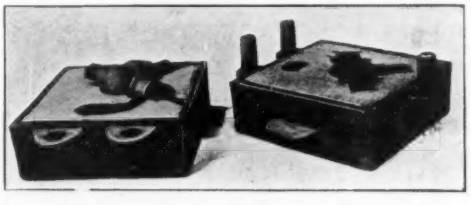


FIG. 7.—MOULD AND CORE USED IN CASTING HIGH-PRESSURE STEAM FITTING.

The castings obtained in this way were invariably clean, but they were not always sound. This unsoundness usually took the form of pinholes in the lug, but sometimes appeared in the barrel. For a long time the authors were unable to trace this difficulty to its source. Eventually the solution was found by working on the following lines:—

Although the castings had been produced as far as possible under similar conditions, one important variable had been present, namely, the duration of the melting of the charge. The furnace worked more quickly at some times than at others. In some cases the charge consisted of pure copper and pure aluminium; in others, of gates and risers of the required composition left over from previous casts. The former took longer to melt. An important consequence follows from this variable, namely, a variability in the amount of gas dissolved in the charge. This quantity will increase with the duration of the melting and the absolute temperature, up to a limit. It will be higher for charges made from pure metals, on account of the greater solubility of gases in these. This difficulty will always be present in making castings under the present practical conditions, namely, by melting in air. It can, however, be minimised, and in the case of the aluminium-bronzes

this has been done as follows: After the melt has been stirred and cleared of dross it should be allowed to remain in the crucible as long as possible before pouring. With the fall of temperature the solubility of the gas diminishes. Corresponding to this there is a liberation of dissolved gas. The lowest temperature at which these alloys can be cast (with slow pouring) is about 50 degrees C. (90 degrees F.) above the temperature at which the alloy begins to freeze. The latter is about 1,040 degrees C. (1,904 degrees F.), so that 1,100 degrees C. (2,012 degrees F.) represents in round numbers the lowest temperature at which it is safe to cast. After adopting these conditions the number of castings showing pinholes or sponginess has been greatly reduced, and while this difficulty still appears occasionally, the authors are now able to produce an average of four good castings out of six.

As a result of the foregoing experiments, coupled with the data on the corrodibility of the aluminium-bronzes given in the Eighth Alloys Report, which have been extended and confirmed by Dr. Rosenhain and Mr. Lantsberry in their Appendix to the Ninth Alloys Report, the authors think they are entitled to claim that most of the requirements of high-pressure castings have been met.

It was considered desirable, however, to extend the testing of these bronzes in two directions, (1) mechanical strength, and (2) deterioration.

Mechanical Strength.

The tensile tests quoted were obtained with small test-pieces. In view of the fact that large test-pieces give more or less inferior results, cylinders 9 by 3 in. were cast in sand under the same conditions as the valve-blocks. These test-pieces were thus slightly larger than the barrel of the block. They were machined so as to give a hollow cylinder with a ¾-in. bore, and thus presented considerable similarity to the actual barrel of the valve-block. The following results were obtained: —

Aluminium	Ultimate Stress.	Elongation on 2 ins.
Per cent.	Tons per square inch.	Per cent.
9.0	25.04	29.6
9.5	28.01	21.0
10.0	26.23	13.0

These values, though not as good as those obtained with the small sand castings of the Eighth Alloys Report, are satisfactory in spite of the fact that each test-piece showed considerable sponginess. The specimens had been cast at temperatures varying between 1,200 degrees and 1,250 degrees C. (2,192 degrees and 2,282 degrees F.). In view of the fact that the average temperature was about 100 degrees C. (212 degrees F.) above that at which the best results with the valve-blocks had been obtained, another set of test-pieces of the same size was cast at 1,100 degrees to 1,125 degrees C. (2,012 degrees to 2,058 degrees F.). They gave the following results: —

Aluminium.	Ultimate Stress.	Elongation on 2 ins.
Per cent.	Tons per square inch.	Per cent.
9.0	18.12	26.0
9.5	21.60	14.5
10.0	20.32	7.0

The fracture of these specimens showed that they were perfectly sound. Notwithstanding this, the tenacity and ductility were inferior to those of the unsound pieces cast at a higher temperature. Accordingly it appears as if some sacrifice of these properties must be made in order to obtain castings entirely free from sponginess or pinholes, so long as they were prepared under conditions which permit of the solution of gases during melting. The values in the above table approximate most closely to those of the hydraulic castings themselves, and may be regarded as typical.

As regards deterioration, these tests are in progress at the time of writing.

High-Pressure Steam Tests.

In the previous tests the aluminium-bronzes containing from 9 to 11 per cent of aluminium have been shown to be capable of holding hydraulic pressures of between 14 and 20 tons. These correspond to between 2,200 and 3,200 atmospheres' pressure. As these are well above the requirements of castings for high gas-pressures, the authors did not consider it necessary to initiate any special tests of this kind. There is no doubt that these bronzes possess the requisite qualifications for this purpose, so long as the gas is at the ordinary temperature.

The case is, however, different with high-pressure steam, particularly with superheated steam, because prolonged exposure at the temperatures reached may cause a more or less rapid deterioration of the bronze. Accordingly two high-pressure steam-valves were cast. As these were small and thin (the wall-thickness being 0.25 in.) it was deemed safe to cast them with the 10.5 per cent. bronze. Fig. 7 shows the mould and core in position, and Fig. 3 the casting and gate. No riser was used. Each casting appeared perfectly clean, with a smooth surface. They were tested on the hydraulic pump up to 1.5 tons pressure without showing any deformation or leak. One of them was tested for a short time at a steam pressure of 180 lbs. per square inch, and held this pressure satisfactorily. Arrangements were then made to test them for a long period with high-pressure steam under "service" conditions. The results of these tests will be communicated in due course.

Birmingham Metallurgical Society: Presidential Address.

Professor T. Turner delivered his presidential address to the Birmingham Metallurgical Society at the Municipal Technical School, on December 6. Speaking of the diffusion of metals, he said it was formerly the custom to divide metals into those which were volatile and those which were non-volatile, but such distinction no longer existed since, in the electric furnace, all metals could be converted into vapour. Metals resembled water or other liquids, in that they evolved vapour at temperatures well below their melting point. The vapours of metals obeyed the ordinary law of gaseous diffusion, and, even in solid metals, when near their melting point, considerable internal admixture or diffusion might take place. Among special applications of the principle of diffusion mentioned by Professor Turner were the fact that base bullion is remarkably uniform in composition, as are also the metals used for coinage purpose. In the annealing of cast brass, which, as first made, was variable in composition, the diffusion of the zinc led to a great improvement in the uniformity and texture. The formation of silicates by heating together finely-powdered materials well below their melting points was another important example of diffusion which, doubtless, had its application in the fire-brick trade and the china industry. The conversion of iron into steel, with the absorption of carbon, was instanced, finally, as a remarkable example of the diffusion of an element in a metal at a temperature far below the melting point.

Electric Power Required to Melt Metals.

By Professor Joseph W. Richards.

After experience has brought an industry, or any particular operation, as far as it can, further progress depends upon a more refined method of getting at the facts involved. At this point it becomes necessary to study the mechanical, physical, thermal and chemical principles involved. This study can be best done in the laboratory.

To make a specific application, let me illustrate by citing the melting of brass. We put the metal into a crucible and the crucible into a fire, and after a while we have the molten metal desired. After centuries of experience, have we reached the best possible result, the highest full efficiency? We may think we have, until a bright inventor comes along with an improved melting furnace which melts 50 per cent. more brass for a given quantity of fuel. Then we commence to ask ourselves, "What is the greatest efficiency possible?" Or another inventor comes along with an electric furnace for melting brass. How can we tell the efficiency of our electric furnace?

In melting metals a practical man can tell us from his experience how much coke it takes to melt a ton of given metal and bring it to the proper temperature for casting, in a given furnace. Another metallurgist can tell us how much oil would be required in another type of furnace, and we could thus roughly compare the efficiency of these furnaces with each other; but the comparison would be rather upon the basis of cost than on the absolute scale of how near to the theoretically possible each was working.

The proper basis for real information in this field lies in the measurement of the maximum calorific powers (heating values) of the different fuels used. The calorific powers of the fuels are determined in the laboratory by their complete combustion in a calorimeter, and the heat measured in water units. Thus we know that pure carbon (dry charcoal) has a calorific power of 8,100, which means that one kilogram of it in burning will raise the temperature of 8,100 kilograms of water one degree Centigrade, or that one pound will raise the temperature of 8,100 lbs. of water one degree Centigrade, or that one pound will raise the temperature of 14,580 lbs. of water one degree Fahrenheit (14,580 B.T.U.). The kilogram units are used in all scientific work in Europe and America. They are also used in practice wherever the metric system is used. Pound units and Centigrade degrees give the same numbers, and therefore may be used if anyone prefers, but the pound Fahrenheit (B.T.U.) units have to be expressed in entirely different numbers.

The heating value of electric energy is known with accuracy. One kilowatt-hour furnishes 860 kilogram heat units (calories), if entirely converted into heat energy, without loss. This is 1,897 pound-calories, or 3,414 B.T.U. One English h.p.-hour is nearly three-fourths of this:—642 calories, 1,416 pound-calories, 2,549 B.T.U.; one metric h.p.-hour is 635 calories, 1,400 pound-calories, or 2,520 B.T.U.

The actual heat content of a melted metal can be measured experimentally by pouring some of it into water in a calorimeter and measuring the heat given out in cooling to solid metal at the ordinary temperature. This is best expressed in calories per kilogram of metal, or pound-calories per lb. of metal—numerically the same figure. B.T.U. per lb. would be 1.8 times that number. This quantity of heat represents the useful effect of your furnace, the part of the heat of combustion of the fuel which has been put just where it was needed—the usefully applied heat.

By assuming that a metal needs to be heated for practical purposes 10 per cent. above its melting point (on a very large scale, 5 per cent. might answer), we can construct the following table of calories necessary to put into one kilogram of metal (pound-calories per lb.), in order to melt and superheat it to the point needed for casting:—

	Melting Point. C°.	Latent heat of fusion. C°.	Heated in Just melted. Lb.-calories.	Melted Metal. Superheated 10 per cent. Lb.-calories.*
Magnesium ...	750	58	246	271
Aluminium ...	645	100	258	278
Iron	1,600	69	336	368
Nickel	1,450	68	290	312
Cobalt	1,500	68	329	359
Copper... ...	1,085	43	162	176
Zinc	419	23	68	73
Silver	962	24	89	96
Cadmium ...	322	13	32	34
Tin	232	14	28	29
Antimony ...	632	40	74	78
Plantinum ..	1,775	24	89	102
Gold	1,051	16	51	55
Lead	326	4	16	17
Bismuth ...	276	12	21	22
		ALLOYS.		
50 Tin ... } 50 Lead ... }	202	10	12	20
15 Tin ... } 85 Copper }				130
35 Zinc ... } 65 Copper }				130
Cast Iron ...				250
Steel				315

An application of our principles, by way of illustration, may be made to brass or bronze, containing 130 calories per kilogram (130 pound-calories per lb.), when ready for pouring.

Coke Necessary.—At a calorific power of 7,000 calories it would require $130 \div 7{,}000 = 0.019$ kg. per kg. of bronze, at 100 per cent. efficiency of application of heat; or 1 lb. of coke might melt $1 \div 0.019 = 54$ lbs. of metal. If in practice we melt 10 lbs., our melting efficiency is $10 \div 54 = 0.18 = 18$ per cent.

Oil Necessary.—At a calorific power of 11,500 calories (20,700 B.T.U. per lb.), it would require, at an efficiency of 100 per cent., $130 \div 11{,}500 = 0.0113$ kg.; or one part of oil might melt $1 \div 0.0113 = 88$ parts of alloy. If in practice it melts 15 times its weight, the thermal efficiency is $15 \div 88 = 0.17 = 17$ per cent.

Electric Power Necessary.—To supply 130 calories requires theoretically, allowing for no loss, $130 \div 860 = 0.15$ kilowatt-hour, or 0.20 h.p.-hour to melt 1 lb., requiring 130 pound-calories, would require 0.07 kw.-hour, or 0.09 h.p.-hour. Or 1 kilowatt-hour should melt 6.7 kilograms, or 14 lbs., at 100 per cent., efficiency. If 1 kw.-hour actually melts 3.3. kg., the thermal efficiency of the furnace is 50 per cent.

Comparative Values.—If 1 lb. of coke melts 10 lbs. of metal, 1 lb. of oil melts 15 lbs.; and 1 h.p.-hour melts 5.5 lbs., the relative values of these melting agents are:—1 lb. coke = 0.67 lb. oil = 1.8 h.p.-hours; or coke at 16s. 6d. per ton = oil at 25s, per ton = power at 50s. per h.p.-year.

From the foregoing figures it would appear that coke would be everywhere the cheaper; but in Norway, with coke costing 25s. per ton, and electric power not over 40s per h.p.-year, the electric furnace is the

* Abstract of Paper read before the American Brass Founders' Association.

cheaper. Moreover, when the cost of crucibles destroyed, labour and deterioration of metal, is taken into account, the electric furnace may be the cheaper in many other localities than Norway. Besides, some electric furnaces are working at efficiencies nearer to 75 per cent. than to 50.

The Influence of Briquetted Turnings on Cupola Iron.*

In view of the interest now being taken in the briquetting of iron and steel turnings and scrap generally, we print the following from the pen of the inventor of one of the processes now in use.

The fact that the addition of briquetted turnings lowers the carbon content of iron is of practical interest, in view of the failure that has attended all endeavours to produce in the cupola a product that is lower in carbon than the charge, the usual experience being that the percentage of carbon is raised considerably. One point, however, that seems to have escaped notice is, that in a Paper read before the German Foundrymen's Association in 1909, it was stated that the manganese content remains unaltered when briquettes are used, and even seems to be increased, a circumstance that would explain the high tensile strength of the resulting metal, though it is opposed to previous experience with the cupola.

Turning to another point, it has been repeatedly demonstrated that the briquetted turnings do not fall to pieces in the cupola, but melt like the broken pigs; consequently, any deviations exhibited by the product of a charge containing briquettes, in comparison with that from a charge of pig alone, must be attributable to phenomena occurring anterior to the period of fusion. These deviations include—increased desiliconisation and decarburisation, enrichment in sulphur, and the problematical increase in the manganese content.

The briquettes are relatively loose and porous, and become increasingly permeable by gases as they expand under increased temperature. Consequently, an opportunity is afforded for the graphite to burn off in the upper zones of the cupola, thus leaving the iron skeleton exposed to the gases. The experiments of Finkener justify the assumption that the sulphur always present in the furnace atmosphere will unite with the iron of the briquettes before the metal has actually melted, a further opportunity arising later on for the iron, in presence of the coke, to absorb the remainder of the sulphur. This enrichment in sulphur explains the absence of the usual increase in the carbon content. Since it is difficult to prevent this increase of sulphur by employing a slag correspondingly rich in lime, the only course open is to see that the sulphur content of the coke is low. The metal should also be poured as hot and as quickly as possible. To prevent excessive retardation of the formation of graphite, owing to the action of the sulphur, it is sometimes advisable to add a little silicon to the ladle.

It is now established that the formation of air bubbles and pipes in casting is caused by the sulphur content of the iron, and not by the presence of ferrous oxide. Sulphur gives rise to the direct liberation of gas, lowers the fusing point, and thickens the iron—sufficient reasons for explaining porous castings. However, since the method of working with briquettes has become more fully understood, and attention has been bestowed on the influence of sulphur, it is now possible to obtain castings of exceedingly fine grain, and a metal that adapts itself excellently to working.

Whether unusual desiliconisation and the aforesaid problematical increase in manganese content are also due to phenomena occurring previous to the stage of fusion, is difficult to decide in the absence of all reliable experiment. It is possible that the porous structure of the briquettes and the exposed condition of the silicon and iron after the elimination of the graphite may lead to premature oxidation of the silicon and its conversion into a slag constituent. The absorbed sulphur may also play some part in this reaction. It is remarkable that in re-melting cast-iron briquettes a loss of 8 to 10 per cent. should be incurred in melting, the silicon content declining from 2.51 per cent. to 1.27 per cent., whilst the manganese increased from 0.33 per cent. to 0.5 per cent.

What constitutes the desirable feature about briquettes, to those who know how to work them, is not so much that they enable turnings of low value to be improved considerably, but also in the ease with which one can readily and certainly obtain physical properties that were hitherto impossible to produce from analogous material, and at the same cost. The explanation of these properties depends on the combination of a number of factors, including increased elimination of silicon and carbon, and enrichment in sulphur and manganese; and the latter circumstance would greatly facilitate the solution of the problem should its actuality be demonstrated. Even the undoubted tendency of the materials that are melted along with the briquettes to retain their manganese content, is sufficient to point to the existence of certain influences. The course of the reactions may be pictured most clearly if attention be concentrated on the carbon first of all. The only way to explain the decrease in the carbon content is by mechanical loss and premature combustion of the graphite, which must be sufficient in extent to more than counteract the factors tending to increase the proportion of this constituent, namely, the decrease in silicon and increase in manganese. The increase in sulphur limits the absorption of carbon, and thus contributes to the attainment of the desired end. A point of equal importance is the condition in which the carbon is present in the alloy. Everything points to the high tensile strength being due to an increased formation of hardening carbon, at the cost of a restriction in the formation of graphite. This is favoured by the decrease in silicon, which leads to a diminution of graphite, and, therefore, to the retention of larger amounts of hardening carbon, and probably to a diminished formation of carbide as well. In proportion as the silicon content declines, the increase in the manganese content becomes more important in the formation of a larger amount of hardening carbons and reduced production of graphite and carbide. All these reactions contribute to the production of an iron approximating in properties to white iron, and this tendency is particularly noticeable in iron obtained by re-melting briquettes without any addition of pig-iron. The product then contains 1.27 per cent. of silicon, 0.5 per cent. of manganese, and 3.04 per cent. of total carbon, and corresponds to light grey iron, suitable for cylinder castings.

All things considered, the employment of briquettes affords a striking instance of how "many a mickle makes a muckle" in building up the properties of iron, and that it is, in all cases, impossible to explain alterations in the character of the metal merely by the influence of a single constituent.

* E. Leber in "Stahl und Eisen."

A Discussion on Blowers.

A meeting of the Birmingham Branch of the British Foundrymen's Association was held at the Birmingham Technical School on Saturday evening, November 26, 1910, when the President (Mr. A. H. Hiorns) presided over an exceptionally large attendance. Six Associate Members and two Associates were elected.

Two Papers had been announced to be read:—(*a*) "Blowers," by Mr. Arthur D. Ellis, of Messrs. Thwaites Brothers, Limited, Bradford, and (*b*) "Fans," by Mr. Cleworth, of Messrs Heenan & Froude, Manchester.

The CHAIRMAN announced, with regret, the receipt of a telegram from Mr. Cleworth, to the effect that he had unavoidably missed his railway connection, and could, therefore, not attend, but would read his Paper on the first convenient date. As a result, the entire evening was devoted to the subject of "Blowers."

MR. ELLIS proceeded to read his Paper, which was illustrated by a series of excellent limelight views. The Paper was published in abstract in our last issue.

Discussion.

The PRESIDENT, opening the discussion, said they would all agree that they had had a very interesting Paper, and a very practical illustration of the various blowers in general use. The author of the Paper would be very glad to answer any questions raised during the discussion.

MR. R. BUCHANAN said he had been unable to arrive at a definite conclusion, and many foundrymen were rather disposed to revert from blowers to fans in cupola practice. Mr. Ellis had stated in the Paper that, when scaffolding occurred in the cupola, there was a diminution in the volume of air pumped into it by the fan. That was because the scaffolding reduced the available area in the cupola, and the fan consequently sent in less air. He (Mr. Buchanan) considered that was rather an advantage. His own plan, when scaffolding occurred, was to shut the air off altogether. The penetration by the air in the cupola was another matter in which it seemed foundrymen were getting away from the old ideas. They were not so very much concerned about the air penetrating into the cupolas as formerly. If the air went into the cupola, it would certainly penetrate if the hole was there to carry it away. The idea was to get as much air into the cupola as possible, with the least pressure. If they could get that with four inches of water instead of twenty, he should consider that the ideal. They must strive to get the greatest volume at the lowest pressure. The point was debatable, but he thought he had expressed the trend of opinion among foundrymen. Mr. Ellis's statement as to the number of cubic feet of air per minute per ton of iron melted did not convey very much to them. They often heard statements on air-volume, but they still sorely needed information on that subject. It would be a great advantage to know the relation between pressure and the amount of air going into the cupola. It was tolerably certain that too much air at too high a pressure was worse than insufficient air at a low pressure, because they could actually damage their iron with high pressures and high volumes.

MR. R. MASON said he felt certain the blower was the most efficient machine for propelling air into the cupola. The type of blower was a debatable question, but he considered the Roots blower a good machine. At the same time, he thought there were better. It would have been more intelligible if the water pressure had been expressed in ounces or in pounds, which was the form familiar to foundrymen. He was very much interested in seeing that the limit of variation in blast pressure was so small. The amount given was rather small, but his experience was that, though makers of blowers promised so many feet of air per minute, they often failed to fulfil their promises. In other cases it was clear there must be more air than there was said to be. He was speaking of 18 to 20-oz. pressure. Mr. Ellis had stated that he had allowed 650 to 750 feet per minute per ton, which would give, calculated on the first-named figure, 39,000 cubic feet per ton per hour. Personally, he would consider 26,000 feet quite sufficient. Remarks had been made about reducing speed when the pressure became too high, but he did not think that was of very much value in the cupola. If they had something which would reduce the speed when the stock in the cupola became low, that would be sufficient. Most of them were blowing their flame right up to the top, and it would be better to reduce speed before that was reached.

MR. W. J. FOSTER said that generally speaking, he was more accustomed to blowing blast furnaces than cupolas. He was very much interested in Mr. Buchanan's remarks with regard to the regulation of blast in cupolas, and he entirely agreed with him. He thought that in cupola practice, as with the blast furnace, where it was sought to maintain a regular temperature in the iron, there was a great advantage in keeping the air supply governed, not by pressure, but by the actual volume passing through the cupola. Everything depended upon the rate of melting. Obviously, the air in the cupola oxidised a certain amount of fuel, and that governed the rate of refining. In cupola practice, it would also to a great extent practically govern the temperature of the metal when leaving the cupola. He was not at the present time inclined to go into the question of the effects of temperature upon cast-iron, as he was engaged upon certain experiments respecting which he proposed to read a Paper shortly before the West of Scotland Iron and Steel Institute. In that he was proposing to show the great differences in various irons both from the cupola and from the blast furnace, such variations being entirely due to temperature. Many people who had not gone into the matter thoroughly would be surprised to know the difference in the carbon contents and the difference produced in the fracture by temperature variation. Personally, he was very well satisfied with the good results he had been able to obtain from the use of blowers.

MR. F. J. COOK said that the question of fan or blower for cupola working depended very largely upon the grade of the metal they had to melt. For very thin work, such as stove grates and radiators, where iron of a very soft nature was required, a fan seemed to be a very desirable machine to use, because the pressure of the blast would have a tendency to keep the metal soft. But where it was desirable to use the blast not only to melt the metal, but as a means of purifying or hardening the metal, the blower was the better machine, because of the higher pressure that could be obtained from it. Taking it for granted that there was a certain volume of air per ton of iron melted which gave the best and most economical working, they had then to consider what the effect would be if that same volume of air was passed into the cupola at a low or high blast pressure. That the action of blast under pressure had a marked influence on metal

was very easily proved. Take, for instance, the Bessemer converter. Molten cast iron was placed in a vessel and blown, and they all knew the great effects which followed, solely attributable to the action of the blast. It must be remembered that the changes were not due so much to the volume of the blast as to the pressure, the whole physical properties of the metal being changed. That fact was now being made use of in a similar manner, though to a less extent in cupola working, and a patent for doing the work effectively had been taken out. That the pressure of the blast had an effect upon the output of the cupola could be shown, though the proof, perhaps, was of a negative character, and not definitely convincing. It would generally be conceded that in American cupola practice, lower blast pressures prevailed than were customary in England. Having followed for a long time the data available with regard to cupola results in the two countries, he had found that the American practice was to allow a sectional area at the tuyere zone of the cupola of about 260 square inches per ton of iron to be melted, whereas, in England, the average was about 175 square inches. That would work out to 8.6 lbs. of iron per square inch-hour for American practice, as against 12.8 for English practice. But in working out actual results, where they were obtainable, it was found that good American practice ranged from 10 to 11 lbs. per square inch-hour, as compared with 12 to 13 lbs. in this country. If the assumption of lower blast pressure held good, it might, in some measure, account for the difference in the results obtained. That the pressure of the blast had a great influence on the physical properties of the metal melted in a cupola was easily proved.

Illustrating this fact, the speaker introduced upon the screen two diagrams, to which some prominence was given in a Paper read by him early in 1910 before the Staffordshire Iron and Steel Institute. The first diagram represented a series of experiments made to ascertain the changes in the metal due to the action of blast pressure when melting No. 3 foundry pig-iron. The diagram showed that the hardness increased directly with the blast pressure, and that the tensile and transverse strengths also increased up to a point, and then fell away again. Several different kinds of iron had been experimented with, and each showed similar results. It was found that the harder the iron melted, the greater were the effects of the blast pressure. It was found, further, that with iron of the harder class, instead of the maximum tensile and transverse results agreeing with the same blast pressure as shown in the diagram, they gradually became divided, the maximum transverse strength agreeing with a lower pressure than that which gave the highest tensile results. A second diagram, representing seventy consecutive days' operation with a hard iron, showed the great effect which hardness has on the tensile and transverse strength of the metal. A striking feature was the division between the peaks of the two curves. The speaker explained that the hardness tests were obtained by means of a drill test. He would like to emphasise the point brought out by Mr. Buchanan with reference to volume. They heard a good deal about what the volume of air should be, and some figures had been given which apparently related to the delivery of air, with no resistance or with only atmospheric pressure. But that did not represent actual work. A great deal of work required to be done in experiments with air volume. But it was not easy to get a volume of air going into the cupola under working conditions. One method of measuring blast pressure was by means of the Flegson cone. But it required to be read very closely, and he was not sure that it was the best apparatus for cupola work. He noticed in a trade journal of September last records of a series of tests which had been made with a turbo-blower, and the apparatus used there seemed to be one very easily applied in ascertaining the effects of air-volume in cupola work. If Messrs. Thwaites would work out that matter, the foundrymen would be deeply interested in it, and it would be of great benefit to the foundry trade generally. (Applause.) A great point had been made in regard to the controlling of the air to make it uniform. Personally, he would not care for an apparatus of that sort, because he would prefer a variable speed motor under blast pressure, employing also a Bristol recorder indicating the blast employed. The question of blast-pressure effects was one he had studied very thoroughly for the past ten years, and by means of blast pressure it was possible to alter the metal so as to produce properly large or small cylinders, and secure a very close degree of accuracy in the way of hardness and tensile strength.

Mr. Jocelyn said he had had some experience with a centrifugal fan, and found that a reduction of the orifice and a reduction of the area of the tuyeres with the fan running at a constant speed had the effect of slightly increasing the pressure, and it should be possible to design a fan which, with a slight reduction of the orifice, would give considerable increase of pressure. It should be possible to get over the slight difficulty that was anticipated. There appeared to be a tendency to reduce pressure in some of the machines. It appeared to him that the centrifugal fan could put forward a very strong case in comparison with the Roots blower on the score of £ s. d. With the Roots blower, it was necessary to take into account mechanical efficiency, but they had to take into consideration also efficiency in volume. The statistics exhibited showed in one of the blowers with regard to the cubic feet of air per minute, an efficiency of 100 per cent., representing 8,800 cubic feet of air per minute, but with another it was 7,300, which, taking into consideration the water difference, represented 83 per cent. of volume efficiency. With a pressure of 28 in. of water, they had 75 to 76 per cent. mechanical efficiency. With a centrifugal fan of moderate size and proper design, they would obtain equal efficiency. A good case had been made out for the Roots blower, but if low pressures were an advantage, the fan could show a better result in actual horse-power per ton of iron melted than the Roots blower. With regard to lower pressures, every foundryman was perfectly aware that to get the same value of air larger tuyeres must be employed.

Mr. Ellis, in reply, said that he agreed very largely with what had been said by Mr. Buchanan in regard to the supply of air volume. But it sometimes happened that more work was required of cupolas than they were fitted to do, and the only way to meet that was to put in more air, or increase the pressure. It was the resistance of the charge in the cupola itself which was the real resistance offered, and not the blowers as had been suggested. That was where the particular value of the blower came in. Some reference had been made to the automatic regulator. His reference to that related to its use for smiths' hearths, and not to foundry practice, but it might be an advantage to control the speed in the way suggested. Something had been said about the quality of iron as affected comparatively by the fan or the blower. It appeared to him that Mr. Cook made his selection of iron inside the cupola, instead of outside. (Mr. Cook: "Both.") Personally, he preferred to select the iron before it went into the cupola, and to blow it accordingly, but while he appreciated Mr. Cook's remarks, he had come to read a Paper on blowers, and not on cupolas. As to ability to produce delicate ornamental castings with fans, he could give them the names of places equipped with the Roots blower, in which the most ornamental fancy work was produced, and with the blower they succeeded in

getting the softest iron in the world. It had been suggested that some cupolas required fans, and occasionally these proved more effective than blowers, but he could produce cases on the other side. He knew an instance where a large company put up a large American cupola to be blown by a fan, and they only succeeded in getting half the iron they anticipated. A blower was substituted, with the result that the cupola came up entirely to expectations. He could cite other instances of the same sort. In particular, great mistakes were made in regard to the amount of horse-power provided. It was better to consult the manufacturer of the blower as to the amount of horse-power necessary to do certain work. Before the matter was carried further, he thought it would be better for the Paper to be read, marked, learned and inwardly digested, and he would be pleased to answer any questions after the publication of the Paper that might be submitted to him. A number of points had been raised which were very difficult to settle, and could be best settled by a personal interview, but he and his colleague would do their best to answer their questions fairly and squarely. Questions could be forwarded to him by correspondence through the Secretary.

A hearty vote of thanks was accorded to Mr. Ellis and Mr. Johnson on the proposition of the PRESIDENT, seconded by MR. COOK, the latter speaker remarking that he thought it was a wise suggestion on the part of Mr. Ellis to reply to questions by correspondence. A number of points had been raised which might be best dealt with in that way, and the answers could appear in the "Proceedings."

[NOTE.—Owing to a typographical error, the formula in the appendix on page 657 of our last issue was wrongly quoted. It should read:—Decrease in volume due to compression $= \frac{C \times 15}{P + 15}$

Recovering Metal and Charcoal from Crucible Skimmings.

An interesting process for dealing with metal drosses has been patented by the Metal Dross Economy Company, Bristol, Conn., U.S.A., the process consisting, briefly, of skimming the drosses from the crucible in the usual way, but letting them fall into a pot of water instead of on a skimming heap, keeping them wet until time to separate them through a series of superimposed sieves through which they are washed by water. It is claimed that 60 per cent. more skimmings can be saved in this way than by the use of a stamping mill or crushing barrel, as in the latter all of the smallest shot and thin pieces are ground up and lost, and that 90 per cent. more is saved than by any other way where no crushing machine is used. To show the waste of the old process, 60 lbs. of clean metal that had passed a No. 30 sieve was mixed with ashes taken from the casting shop fires and ground. Including the metal that was in the ashes only 21½ lbs. of clean metal was recovered, proving that the amount of fine stuff that is ground into powdered dust becomes lighter than the hard cinders and is washed away by the water. The above-mentioned process of the Metal Dross Economy Company, by contrast, is claimed to save everything, including the oxides.

The skimming tank is a cast-iron box, 20 in. by 22 in., 16 in. or 20 in. deep, with a steel top in which there is a funnel-shaped opening about 8 in. square. Over this is a shield at an angle of about 45 degrees, which protects the caster from the heat, dirt and much of the smoke. The tank should be set in the floor, so that the top is about 4 in. or 5 in. below the top of the crucible, and should be kept filled with water to within 2 in. of the top. The skimming of dross into water immediately stops the spelter smoke and does away with the skimming heap, conducing to a clean casting shop. As soon as the dross strikes the water all oxidation of metal ceases, whereas by the old way the brass continues to oxidise even after it has been skimmed and lies on the heap. The zinc oxide immediately separates from the metal upon reaching the water and takes the form of different sized pellets.

At the end of the day or any other convenient time, the tank is cleaned out. The skimmings should not be allowed to dry, as the oxide of zinc will then adhere to particles of the brass and become much harder to clean off, and the very fine shot metal will also be more difficult to save. The skimmings may be put in a barrel and kept wet until a more convenient time for cleaning. By the "Economy" process all the charcoal that remains unburned is saved, and may be returned to the crucibles. The tanks are made in two sizes, No. 1 holding the skimmings from 50 No. 25 crucibles, and No. 2 from 60 No. 70 crucibles. The water will remain at about the same depth in the tanks, no matter how much dross or charcoal may be skimmed into it, due to the oxides taking up some of the water and some of the water evaporating.

The metal dross separator, which separates the oxides from the metal, is made of cypress wood, and is in the form of a tier of drawers with wire cloth bottoms of different meshes secured with cleats and brass screws, so that they may be easily renewed. The dross from the tank, about a scoop shovelful at a time, is put into the top drawer, and any lumps of coal or sand balls containing brass or large pieces of brass are taken out. The sand balls can be run through a crushing machine or sold as junk in that form. Everything that remains in the other drawers goes back to the casting shop, and can be used either wet or dry. If used wet, it is better to put it in the crucible when the pot is charcoaled, putting it on top of the charcoal, or on top of chips, or in any way so that the water will not get under the metal. It also makes a good flux and helps to stop oxidation, and does not gum or stick up the pot. In most foundries the metal saved one day is used the next, and divided in about equal amounts to each crucible. What little brass works through the bottom cloth into the water reservoir of the separator can be rewashed, so that there will be nothing but the oxides that will wash away, and they may be saved if desired, although after going through the second process they have little value. It takes only about 15 minutes to clean a tank of skimmings. The operation consists simply of turning a hose in the top of the separator and letting the water percolate through, being careful not to overload the apparatus.

Foundry Plant and Equipment.

Automatic Annealing Furnace.

A new form of automatic annealing furnace which contains a number of interesting and original features is shown in the annexed illustrations. It has been designed by Mr. Cliff M. Bleyer, of the Hawley Down Draft Furnace Company, of Chicago, for annealing at low or high temperature small castings or stampings of iron, steel or bronze, and is entirely automatic in operation, being self-feeding, self-distributing, and self-charging. It is stated that when supplied with materials and heated to the proper temperature, it does its work practically without attention and delivers the annealed product to any point desired. All that is needed for the operation of the furnace is a suitable supply of oil or gas, and an ordinary 110-volt A.C. or D.C. electric circuit. From particulars recently published,* we append the following details of construction.

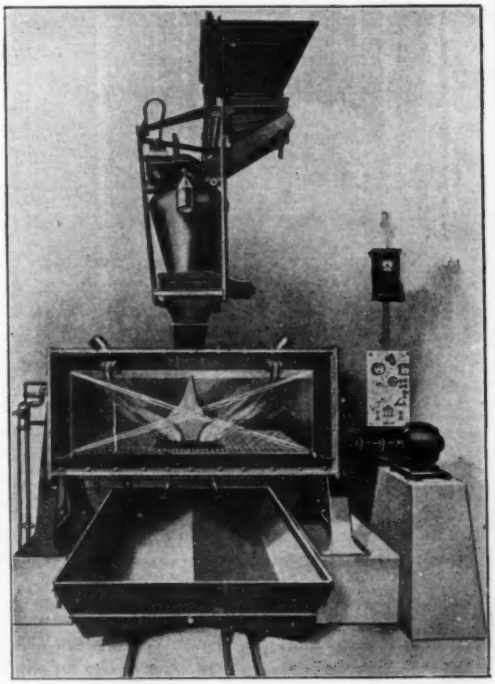


FIG. 1.—FRONT VIEW SHOWING DISTRIBUTING WALL.

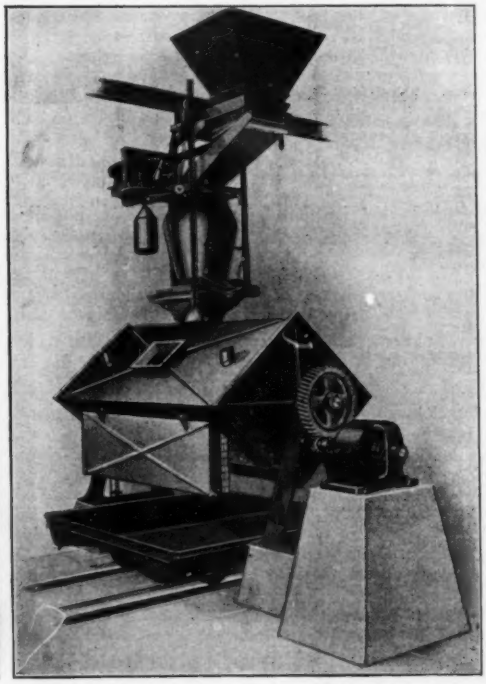


FIG. 2.—VIEW SHOWING FURNACE TILTED FORWARD IN DISCHARGING POSITION.

AUTOMATIC ANNEALING FURNACE.

The furnace consists of a rectangular box-shaped shell made of six heavy cast-iron plates and lined with firebrick. The thickness of the firebrick lining varies from 4 to 8 in., depending on the size and capacity of the furnace. The furnace illustrated is 6 ft. in length and 3 ft. square, in section, the thickness of lining being about 5 in. It is designed to handle 200 lbs. of small castings in one charge. Between the firebrick and the cast-iron shell is a sheet of asbestos felt ½ to ¾ in. thick, depending on the size of the furnace. This non-conducting sheath reduces the radiation to a minimum.

The furnace is carried on trunnions, which are connected by a train of gears by which the furnace is tilted. One of the important features of the design is the arrangement of the brick inside, as shown in Fig. 1. Directly under the charging hole is a wedge-shaped dividing wall of firebrick, which deflects the charge and distributes it evenly over the bottom of the furnace. The slope of the deflecting surfaces is so arranged that the castings slide down easily and drop lightly to the bottom of the furnace without injury or breakage. The lower part of the deflector is cut away, as shown, so that the flame entering from below on either side is directed towards the ends of the furnace, but does not come in direct contact with any of the pieces being annealed.

Above the furnace is a large supply hopper which is filled either by a conveyor or from the room overhead, or any other suitable means. This hopper is fitted with a valve in the bottom, operated by a solenoid controlled by an electric clock, and may be of any convenient capacity from one to one hundred tons. Between the hopper and the furnace is an automatic scale. The method of operating the furnace is as follows:—At a predetermined time the clock, through the solenoid, opens the valve in the hopper

* "The Iron Trades Review."

so that the castings or materials to be annealed discharge on to the automatic scale. The scale is also arranged in connection with the solenoid so that when a given weight of material has been discharged the hopper is automatically closed and the charge is dropped from the scale into the furnace and is evenly distributed over the furnace bottom by means of the firebrick deflector described above.

After the charge has been in the furnace a certain length of time, which time is adjustable at the will of the operator, the electric clock starts the tilting motor, which tilts the furnace to an angle of 45 degrees, first in one direction and then in the other. In this way the material is automatically shuffled without manual labour, and is heated on all sides uniformly. At any other predetermined time, after the furnace is charged, the electric clock again operates the tilting motor, only in a different manner. This time the furnace tilts forward and the door is opened, as in Fig. 2, dumping the entire charge into the truck, which is shown beneath the furnace. The action of the truck in leaving its station reverses the tilting motor, whereupon the furnace rights itself and closes the discharging door. It then receives another charge of metal from the scale and the cycle is repeated.

To insure the successful automatic operation of the furnace as outlined above, ingenious electrical apparatus has been designed by the General Electric Company.

A Foundry Grab Bucket.

A grab bucket for foundry use suitable for handling sand and for cleaning up the floor, which can be operated by the regular foundry crane, is shown herewith. In operation this bucket is merely picked up by the hook of any ordinary travelling crane, and is manipulated entirely by the crane and the single tripping line. It may be hooked onto or off in an instant, leaving the crane free for other work.

The illustration shows the bucket lowered, ready for gathering its load. Two wire ropes, which are deadened in an equaliser fixed to the framework, carry the bucket, and from their point of fastening, the ropes lead downward around the pulleys in the tackle block and then up again, terminating in a heavy cast-steel yoke, which is placed over the crane hook.

When the crane hook is raised with the bucket in the position shown, the jaws of the bucket close, picking up the load. By means of a linkwork the tackle block moves up in a straight line. To discharge the contents of the bucket, the tripping line attached to the tripping lever is pulled, which disengages a hook connecting the main bucket pivot to the tackle block. This allows the pivot centre to descend, and the bucket to open and discharge its contents.

In either closed or open position the bucket may be carried about, raised or lowered by simply manipulating the crane. When lowered to the ground, as soon as the jaws strike the stress on the tackle block is relieved, and, since the crane hook continues to descend, the tackle block descends in an arc until the hook on the under side of the tackle block again catches the main pivot centre, restoring the mechanism to the position shown. The heavy chains limit the opening of the bucket leaves or jaws, and are connected at the top to spiral springs which absorb the slight shock incidental to the opening of the bucket.

The bucket is designed as a scraping tool, and is used for the entire handling of sand to and from the bins or pile, and is being employed in foundries for levelling off and cleaning up the floors after the flasks are shaken out. The capacity of the bucket is 1½ cubic yards, and the weight when empty about two tons, the weight with contents being about four tons. The floor space covered when the bucket is spread open is 6 ft. by 6 ft., the object being to cover as much space as possible.

The makers of this apparatus are Messrs. Pawling & Harnischfeger Company, Milwaukee, U.S.A.

A Pneumatic Respirator for the Cleaning Room.

In the current issue of the "Journal of the Royal Society of Arts," Sir Henry H. Cunynghame, K.C.B., describes and illustrates a new form of respirator which he has designed for preventing the inhalation of dust by workmen. He states that it was suggested to him during a recent visit which he paid to the granite-working factories at Aberdeen, and claims that it is applicable to dust or fumes of all sorts, whether heavy or light.

Respirators, remarks Sir Henry, as is well known, are very oppressive to wear. If they are too porous, they do not arrest the dust; if they are sufficient to

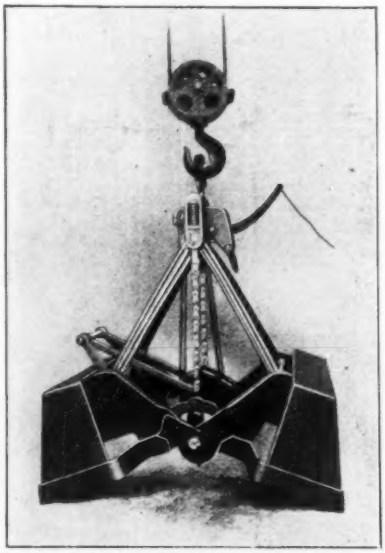


FIG. 1.—GRAB BUCKET FOR FOUNDRY USES; BUCKET READY TO TAKE UP LOAD.

arrest the dust, they impede respiration to an extent that renders them almost unbearable to a man who is doing hard work, and they cause the exhaled breath to be breathed over again. To obviate these inconveniences, I suggest the following plan:—

Let the respirator consist of a copper-shaped vessel *a* put over the nose and mouth, and with the edges bent so as roughly to fit the face. Around the interior edges fit some strips of fur, such as that of a rabbit or cat, sufficient to fill up the interstices between the face and the copper vessel. In the vessel lead a small metal pipe fitting on to a rubber pipe *b* attached to the reservoir of an air bellows. The rubber pipe is to lead up about 6ft., and then be tied to a movable jointed bracket K up near the ceiling of the room. By this arrangement the workman can move freely about and bend his head. The air, rushing in from the air receptacle of the bellows, fills the copper vessel, supplies what he needs for breathing, and escapes through the rabbit skin at the sides It is impossible for any dust to be inhaled. It will not do to work such a respirator from the air-compressors

that are used in driving the pneumatic granite-dressing tools, firstly, because it becomes icy cold as it expands, and secondly, because it is impregnated with oil. Nor is this needful. A bellows of wood and leather, drawing the air from some pure source, at a pressure of some 3 to 4 lbs. to the inch, is all that is needed. Inside the mask the air would, of course, have the effect of continually clearing away the exhaled breath, so that at each breath the workman would breathe fresh air, and not, as in a respirator, keep continually inhaling air already contaminated by his breath.

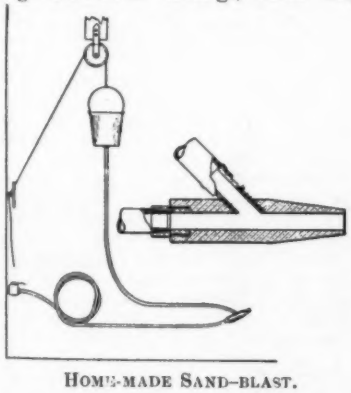
Sir Henry concludes with the remark that a rough trial in a factory has convinced him of the prac-

A PNEUMATIC RESPIRATOR.

ticability of this method, and he thus places it on record, so that it may become public property, and free to anyone who chooses to use it.

A Home-Made Sand Blast.*

A novel sand-blast rig is in use at our shop and for a home-made device it is doing good work. We had a large number of castings, which had to be



HOME-MADE SAND-BLAST.

smoothed up nicely inside and, owing to their irregular shape, it was quite a problem to do the job as the specifications called for. arious methods were tried without success. Finally one of the men suggested buying a sand-blast outfit, but as we had compressed air and lots of sand handy, and were a little bit pressed for time, the foreman decided to let the man make his own sand blast rig. He took a piece of stock bronze about 2 in. in diameter by 8 in. long and, after turning one end down for a nozzle, drilled a small hole through the centre of the piece from end to end. Another hole was drilled from one side, joining the centre hole at an angle of 45 degrees, as shown in the sketch. At the end a nipple was screwed in and fitted to a copper pipe, which had three or four coils in it. This pipe was fitted to the main air pipe through a hand valve. The coils in the pipe were for convenience in handling the contrivance by giving it flexibility, so it could be moved in any desired direction. Another nipple was fitted at the side and to this was connected a rubber hose, which led to the bottom of an ordinary galvanised iron pail. Another nipple had been fitted in the bottom of this pail and the end of the rubber tube was attached to it as shown. The pail was filled with sand and by means of a rope attached to the handle, the pail was hoisted to a height of about 15 ft., and then gravity and the suction created by the compressed air rushing past the mouth of the rubber tube sent the sand out of the nozzle with sufficient force to clean up the surface upon which it projected.

* Frank Rose, in "Modern Machinery."

Hydraulic Pig-Iron Breaker.

The accompanyings cuts, Figs. 1 and 2, depict a hydraulic pig-iron breaker made by Messrs. Bopp & Reuther, of Mannheim-Waldhof, Germany. The outstanding feature of this mechanism is its simplicity of operation. By its use, one man can break per hour 100 pieces of pig-iron of 1 cwt. each without any effort; all he has to do is to put the pig-iron on the machine, and to open the distributing valve with a kick, when the pig-iron pieces are broken on one side at a certain length and fall from the machine without having to be removed by hand.

The working of the machine is effected in the following fashion:—The pig-iron is placed into the

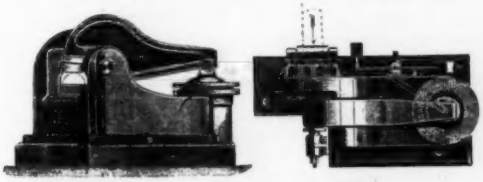


FIG. 1. FIG. 2.
HYDRAULIC PIG-BREAKER.

opening of the frame against a buffer, which regulates the length into which it has to be broken, and is fastened there by a wedge. A kick upon the reversing lever puts the piston under pressure; this acts upon the long lever, which by means of a stout gearing breaks the pig-iron. By automatic reversion the piston sinks, when the wedge is taken out and the piece of pig-iron pushed along for further breaking.

For breaking pieces of pig-iron direct from the truck without further handling, the breaker may be fitted on a movable frame, so that the pieces of pig-iron have only to be taken out of the truck and placed in the breaker. When broken they simply fall into a case or a tipping wagon for further transmission.

Inventions.

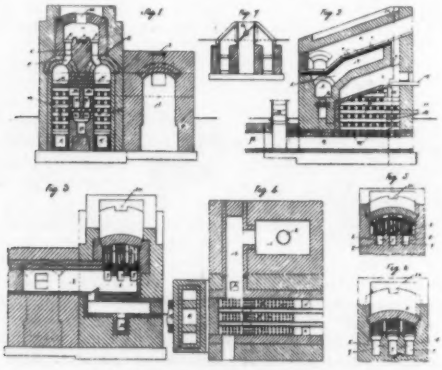
Applications for Patents.

An asterisk indicates that a complete specification accompanies the application. When inventions are communicated the names of the communicators are in brackets.

27,493. Construction of moulding box. J. F. Faries, 173, Fleet Street, London.
27,506. Joining together of metal plates, etc. E. B. Koopman and Pontelec Welding Patents, Limited.
27,616. Moulds and moulding. J. C. Sellars, 68, Bridge Street, Birkenhead.
28,126. Electric furnaces. M. Ruthenburg.
28,241.*Apparatus for cutting, milling, and welding iron water tubes. A. Vesely.
28,283.*Apparatus for testing hardness. Norma Compagnie G.m.b.H. and J. Kirner.
28,463. Flux for cast-iron brazing. Lancashire Cast Iron Brazing Company, 54, Melbourne Street, High Bank, Gorton, Manchester.
28,536. Electrodes for electric furnaces. M. Ruthenburg.
29,184.*Aluminium bronze. P. H. G. Durville.
29,219. Stoppers and nozzles for ladles used for teeming molten metals. Steel, Peech & Tozer, Limited, and J. Hunter, 24, Norfolk Row, Sheffield.
29,277.*Ramming machines. (Maschinenbau - anstalt Humboldt, Germany.)
29,299. Revolving electric furnaces. O. Serpek, 60, Queen Victoria Street, London.
29,376.*Casting of metal. L. Weiss.

Abstracts of British Patent Specifications recently accepted.

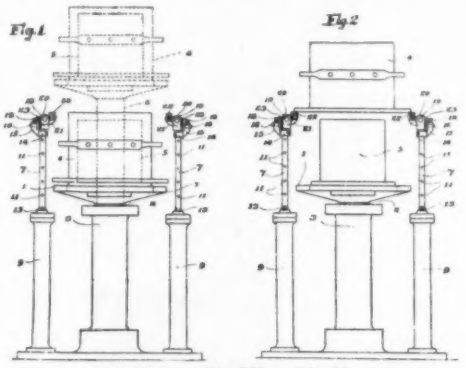
28,229 (1909). *Heating Furnaces.* R. F. Hislop and G. R. Hislop, Junr., Underwood House, Paisley.—The waste gases from the furnace pass down through one or other of the chambers or regenerators 13, and thence through the gas valve 18 to the chimney, and damper at the secondary air opening 23 of the regenerator being closed. The secondary air for combustion of the producer gas is admitted through the gas valve 18 and passes up through the other previously heated chamber or regenerator 13^1 and thence through the supplementary opening 21^1 to the combustion chamber, the damper 12^1



Heating Furnace, by Hislop.

at the inlet to the chamber or regenerator at the top being closed. The air thus becomes highly heated before entering the combustion chamber, and before mixing with the gas from the producer and thus securing a high temperature in the furnace. By the reversing of the gas valve and the manipulation of the dampers, the waste gases and air are made to travel through the regenerating chambers alternately. Instead of taking the gases off through the openings in the bed, opening or openings 24 may be made in the arch of the furnace suitably connected with the chimney.

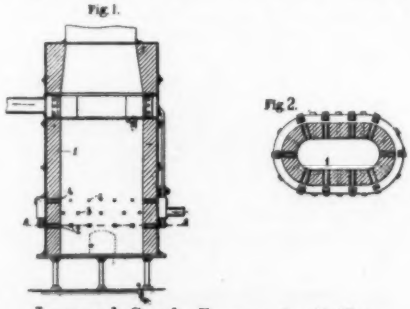
12,789 (1910). *Moulding Machines.* J. B. Neesham, 89, Industry Road, Sheffield.—Fig. 1 is a front view of a moulding machine shown with the side carriers in the operative position, the flask being shown in full lines in the lower position, and in dotted lines in the raised position; Fig. 2 is a front view of the machine showing the flask supported on the side carriers, and with the pattern lowered away from them. When the mould is raised on the moulding table, the moulding flask 4 (or when a stripping plate is used the edge of the plate) comes in contact with the curved snugs or catches 21 at each side of the machine, and raises the same upwards and outwards out of its path, the snugs 21, after the passage of the flask, again moving into their normal position by the action of gravity or by the action of a spring which may be provided if



Neesham's Moulding Machine.

so desired. On the downward movement of the table 1 the flask (or stripping plate) is retained on the set pins 22 ,at each side of the machine (which set pins have been previously adjusted) while the pattern is, in the usual manner, withdrawn from the mould.

2,130 (1910). *Cupola Furnaces.* A. Baillot, 44, St. George Street, Canada.—The novelty of the invention is contained in the combination of the following features:—(1) A body of substantially elliptical cross-sectional shape, and (2) three or more rows of tuyeres arranged in equidistant horizontal planes in the body in such manner that in any three rows of tuyeres a quincunx is formed by any two tuyeres of the uppermost row with the two tuyeres in alignment therewith of the lowermost row and a tuyere of the intermediate row, the tuyeres of each row decreasing in cross-sectional area from the lowermost row upwardly. Preferably, the major axis of the furnace section is equal to two and a-half times the minor axis, and the periphery of the section comprises two rectilinear parts and two semi-



Improved Cupola Furnace, by Baillot.

circumferences. This combination provides a furnace which renders possible a very uniform distribution of the air in the mass undergoing treatment; only a low pressure is necessary, the air having but a short path

to traverse in order to reach the centre of the mass. Consequently, the slag has no chance of cooling and of creating varying temperatures in the mass which is characteristic of imperfect operation. In addition, the pig will be but slightly decarburised, which represents a very great advantage, because it is thus possible to obtain a good quality pig with very common pigs by the first fusion. Fig. 1 is a vertical section through the furnace; and Fig. 2 is a section taken through the line A—A of Fig. 1. It will be seen that the tuyeres 2, 3, 4, are disposed as above described in the body 1 of the furnace, the shape of which will be apparent from Fig. 2.

New Companies.

ROE & HARRISON, LIMITED.—Capital £2,000 in £1 shares, to carry on the business of ironfounders, etc.

FRICKER'S METAL COMPANY, LIMITED.—Capital £2,750 in £2,500 ordinary shares of £1 each and 2,500 "B" shares of 2s. each.

HOLBORN ENGINEERING WORKS, LIMITED.—Capital £1,000 in £1 shares. Registered office: 21, Eagle Street, High Holborn, W.C.

COMBINATION GAS-STEAM ENGINE SYNDICATE, LIMITED.—Capital £500 in 1s. shares. Registered Office: 9-15, Oxford Street, W.

LITTLE BRITAIN ENGINEERS, LIMITED.—Capital £1,250 in 10s. shares. Registered office: Crown Buildings, Cox's Court, Little Britain, E.C.

DICKIN & LOUND, LIMITED.—Capital £2,000 in £1 shares, to carry on the business of engineers, etc. Registered office: 28, Budge Row, E.C.

MACHINE TOOL AND ENGINEERING ASSOCIATION, LIMITED.—Capital £2,000 in 7,600 founders' shares of 5s., and 2,000 subscribers' shares of 1s.

SHUMAN ENGINE SYNDICATE, LIMITED.—Capital £55,000 in £1 shares, to carry on the business of engineers, founders, manufacturers of engines, etc.

OWNLEE COWL, LIMITED.—Capital £100 in £1 shares, to carry on the business of engineers, etc. Registered office: 9, Southampton Street, Holborn, W.C.

JOHN COCKAYNE & COMPANY, LIMITED.—Capital £500 in £1 shares, to carry on the business of engineers, etc. Registered office: 30, Brown Street, Manchester.

JACKSON & BROTHER, LIMITED.—Capital £40,000 in £10 shares, to carry on the business of engineers, millwrights, etc. Registered office; Bolton, Lancashire.

W. BAYLISS & COMPANY, LIMITED.—Capital £5,000 in £1 shares, to carry on the business of engineers, etc. Registered office: 332-3, Dashwood House, New Broad Street, E.C.

MOORE-HESKETT DIRECT PROCESS STEEL, LIMITED.—Capital £37,500 in £1 shares, to carry on the business of steel makers, etc. Registered office: 17, Victoria Street, London, S.W.

T. A. SAVERY & COMPANY, LIMITED.—Capital £12,000 in £1 shares, to take over the business of engineers and boiler makers formerly carried on by T. A. Savery & Company, at Newcomen Works, Bracebridge Street, Birmingham.

CROSSLEY MOTORS, LIMITED.—Capital £140,000 in £1 shares, to take over the business of motor manufacturers carried on as a branch of their general business by Crosseley Brothers, Limited, and all or any part of the share capital of Charles Jarrot & Letts, Limited. Registered office: Napier Street, Gorton, Manchester.

CORNISH SHOVEL COMPANY, LIMITED.—Capital £1,500 in £1 shares, to carry on the business of manufacturers of shovels, ladles, picks, Cornish ribbles, etc., and to acquire from J. Whitworth and T. A. Pool the Roseworthy Hammer Mills, near Camborne, Cornwall. Registered office: Fore Street, Copperhouse, Hayle, Cornwall.

HYDE WELDING COMPANY, LIMITED.—Capital £1,000 in £1 shares, to carry on the business of welding, brazing, soldering, and working of metals, etc., to acquire from the Vactite Wire Company patent No. 5,232 of 1910 for improvements relating to brazing, soldering, and like methods of uniting metallic substances, and to adopt an agreement with the company and A. C. Hyde.

J. P. SKINNER & COMPANY, LIMITED.—Capital £5,000 in £1 shares, to carry on the business of manufacturers of, and dealers in, springs, founders, converters, rollers, tilters, forgers, and manufacturers of iron, steel and other metals, engineers, etc., and to acquire the business carried on at Spiral Works, Thomas Street, and Spiral Works, Guernsey Road, Heeley, both in Sheffield, as J. P. Skinner & Company, and to adopt an agreement with Harriett Skinner and J. C. Skinner. Registered office: Spiral Works, Guernsey Road, Heeley, Sheffield.

Trade Talk.

THE CASTLE WORKS, Hadley, near Wellington, have been acquired by Joseph Sankey & Sons, Limited, Bilston.

MR. H. H. CRESSWELL, 13, Summer Row, Birmingham, has been appointed sole British agent for Herr C. Schniewindt, Neuenrade, Westphalia.

THE ORION STEEL COMPANY (SHEFFIELD), LIMITED, 49, Bailey Street, Sheffield, have established a branch at 65, Fenchurch Street, London, E.C.

THE Dundee Technical College has just placed an order for a testing equipment with W. & T. Avery, Limited, of Glasgow and Birmingham.

A FIRE broke out recently in the works of Wm. McBride & Son, mechanical engineers, of Merchants Quay, Cork, doing considerable damage.

MESSRS. WILMER & SONS, ironfounders and stove manufacturers, London and Bristol, have received the Royal Warrant of appointment to King George V.

COLE, MARCHENT & MORLEY, LIMITED, of Bradford, have acquired the works of Thorton & Crebbin, Limited, Hammerton Street Iron Works, Leeds Road, Bradford.

THE ANDERSTON FOUNDRY COMPANY, LIMITED, of Port Clarence, Middlesbrough, are supplying 75,000 wrought-iron tie bars to the East Indian Railway Company.

THE SANDYCROFT FOUNDRY COMPANY, LIMITED, of Sandycroft, near Chester, have acquired the businesses of Messrs. W. O. Rooper & Company and the Epstein Accumulator Company.

THE HOFFMANN MANUFACTURING COMPANY, LIMITED, engineers, of Chelmsford, are extending their works, and the plans of the extensions have now been passed by the Chelmsford Town Council.

IT is reported that S. Osborn & Company, Limited, of the Clyde Steel Works, Sheffield, is associated with the new South African Steel Corporation, which has been registered with a capital of £150,000.

MESSRS. H. A. NEALE and G. J. FREUND, lately with Crompton & Company, Limited, have established themselves in business under the style of Neale & Freund, Limited, 31, Budge Row, Cannon Street, E.C.

THE fifth and sixth lectures on the "Law Relating to Engineering," to be delivered before the members of Junior Institution of Engineers, have been postponed from December 7 and 19 to January 16 and 30, 1911.

AN interesting lecture on "The History and Practice of Lubrication in Marine Engines" was given by Mr. J. Veitch Wilson, the well-known authority on oils, before the Institute of Marine Engineers, last week.

EDGAR ALLEN & COMPANY, LIMITED, of the Imperial Steel Works, Sheffield, have appointed Messrs. Schrock & Squires, 291, Pearl Street, New York, as their agents in the Eastern American States for the sale of tool steel.

THE TYNE BRASS AND COPPER TUBE MANUFACTURING COMPANY, LIMITED, of Jarrow, have secured a contract from the East Indian Railway Company, for 2,805 brass boiler tubes, along with a large quantity of copper tubes.

THE representatives in this country for the Fairwell pneumatic moulding machine, which we described in our last issue, are Messrs. J. W. Jackman & Company, Limited, Caxton House, Westminster, at whose Manchester house they are on show.

MESSRS. W. V. DEWHURST AND H. DEWHURST have taken over the business of general ironfounders, formerly carried on at Reliance Foundry, Warren Street, Attercliffe, by Messrs. Johnson & Company, and will trade under the style of Dewhurst Bros.

THE VULCAN FOUNDRY COMPANY, LIMITED, of Newton-le-Willows, have just received from the North Western of India State Railway an order for 35 locomotives. They are to be of the eight-wheeled coupled standard type of goods engines and tenders.

THE ROYERSFORD FOUNDRY AND MACHINE COMPANY, of Royersford, Pa., U.S.A., have established a branch at 149, Queen Victoria Street, London, E.C., which will be in charge of Mr. Theodore Butler. The company will stock a large quantity of power transmission machinery at this branch.

THE first meeting of creditors was held recently in the matter of Hall's Iron Company, Limited, of Croydon. The statement of affairs showed gross liabilities amounting to £2,825, of which £2,664 were expected to rank for dividend. The assets were estimated to produce £1,249, or a deficiency of £1,415.

THE Central Cordoba Railway Company, Argentina, have just recently awarded contracts for thirty-five locomotives of various types to Kitson & Company, Limited, of the Airedale Foundry, Leeds, and also an order for 311 freight wagons to the Metropolitan Amalgamated Railway Carriage and Wagon Company, Limited, Saltley, near Birmingham.

THOMAS WILKINSON & COMPANY, LIMITED, Stockton Street, Middlesbrough, have appointed Mr. Norman Burton, of 94, Market Street, Manchester as their sole agent in Lancashire and Cheshire, and Mr. L. M. Wilkinson, of 26/27, Bond Street, Leeds, as their sole agent for the Leeds and Sheffield districts, for the supply of foundry requisites and iron work's stores.

RICHARD NEVILLE & COMPANY, LIMITED, of Llanelly, South Wales, have laid down a Tropenas steel plant at their Wern Iron Works, and are making steel castings up to 12 tons. They have recently received an order for a 150-ton flywheel for installation at new sheet mills. The wheel, which will be 32 ft. in diameter, will be cast in five segments, and the centre in halves.

THE first meeting of the session of the Newcastle Association of Students of the Institution of Civil Engineers was held recently, in the Mining Institute, Newcastle, the retiring President (Mr. D. Balfour, jun., M.Inst.C.E.), in the chair. The address of Mr. E. Box, M.Inst.C.E., the President-elect, on "What Engineering Development has most Benefited Mankind?" was read.

FLOYD & FLOYD, LIMITED, of Coventry, have recently had installed at their Conduit Yard Works, a "New Form Siemens" furnace for annealing their malleable iron castings. Among the other furnaces, built to Mr. Frederick Siemens' plans, which have lately been set to work are a 25-ton pile heating furnace at the works of Messrs. J. B. & S. Lees, West Bromwich, and the tube welding and skelping furnaces at the works of the Wellington Tube Works, Limited, Great Bridge, Tipton.

A SERIOUS outbreak of fire occurred on November 28 last, in the premises of Fullerton, Hodgart & Barclay, Limited, Vulcan Works, Renfrew Road, Paisley. The flames were first observed in the machine shop, which in a very short time was totally destroyed. The portion of the works involved measured 150 ft. by 290 ft., and contained much valuable machinery in course of construction. The total damage is estimated at over £30,000. The origin of the outbreak is unknown.

DAVID BRIDGE & COMPANY, LIMITED, of Castleton, Manchester, have booked an order for a special hydraulic vulcanising press, 14 ft. long by 54 in. wide, to have 12 rams, i.e., six pairs, and to work at a high pressure. The press will have three platens, i.e., two daylights complete with hydraulic charging and discharging appliances. This press is for the extensive works of the Premier Reforming Company, Limited, Walthamstow, for the manufacture of sheeting and other mechanical goods. Messrs. Bridge have also installed three of their heavy grinders, each electrically driven, for the grinding of old rubbers into a state required by the Premier process.

TILGHMAN'S PATENT SAND BLAST COMPANY, LIMITED, Broadheath, near Manchester, since June 11 last have supplied sand blast apparatus to the following firms:—Great Eastern Railway Company, Stratford, London; Davis Gas Stove Company, Limited, Luton; Sperryn & Company, Limited, Birmingham; Rolls-Royce, Limited, Derby; W. H. Allen, Son, & Company, Limited, Bedford; J. Knowles & Sons, Willenhall; J. Southerton & Son, Birmingham; the Avon Malleable Iron Foundry Company, Limited, Bristol; J. Clews & Sons, Limited, Birmingham; the Hoffmann Manufacturing Company, Limited, Chelmsford; Fry, Miers & Company, London; Henry Wallwork & Company, Limited, Manchester; Glaenzer, Perreaud & Thomine, Paris; Archibald Kenrick & Sons, Limited, West Bromwich.

HOWELL & COMPANY, LIMITED, of Wincobank, Sheffield, draw attention to a recent performance of their "Super-Vitrite" high-speed steel. They broke a shaft in one of their rolling mills, and it was essential that it be repaired at the earliest possible moment. A rough forged steel shaft was obtained, 0.40 per cent. carbon, which weighed 44 cwts., and it was turned down to the required dimensions. The shaft was 16 ft. 6 in. long, and of 8 in. in diameter, but a portion 4 ft. 2 in. from one end was left about 10⅛ in. in diameter for a length of 1 ft. 9 in., and another portion 1 ft. 9½ in. from the other end was left, 10 in. in diameter for a length of 3 ft. 2½ in. An endeavour was made to turn the shaft at 68 ft. per minute, but there was so much sand forged into the skin of the material, that it was impossible, the cut sparking like a dry emery wheel. The speed was then reduced to 50 ft. per minute, and that speed was kept till the turning was finished. The finished weight of the shaft was 29 cwts., so that 15 cwts. were turned off. The time taken was 29 hours, of which 13 were roughing, and 16 finishing. During the roughing the material removed amounted to nearly 1 cwt. per hour. The roughing cut was eight cuts to the inch, and the depth varied from ¼ in. to ½ in. This would have been improved if it had not been for the sand in the skin of the material. The tool was only ground twice.

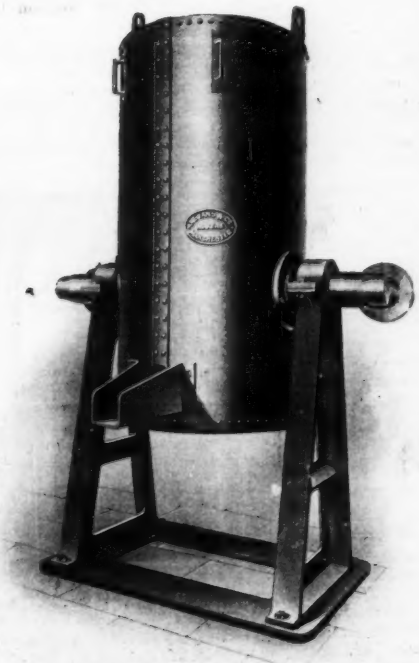
FOR some time past the need of extending the Bridgend Works of Sheppard & Sons, Limited, has been a pressing question, and the recently-made additions form part of a scheme for considerably extending the works. For the present the old foundry has been dismantled, thrown into the erecting shop, and provision made for extending this to the boundary of the land, when such extension becomes necessary. The new foundry, 80 ft. by 40 ft., adjoins the new pattern shop. The cupola fan is belt-driven from a motor which takes current direct from the South Wales Power Company. Material is taken to the charging platform by incline hoist and steam-driven gear. An interesting feature of the foundry equipment is the travelling crane which consists of a radial jib crane, with balanced jib, mounted upon a long girder base, which base is fitted with two cast-iron travelling wheels in tandem, and grooved to fit the single rail. One of the wheels is actuated along the track through a hand wheel and spur gear. The top of the pedestal is fitted with a roller guide working between two channel irons, which, together with the rail, extend the full length of the shop, and out over the stocking ground beyond. The lifting capacity of this crane is 4 tons, and as the jib arm is capable of working in a complete circle it serves the whole floor of the foundry and stocking ground. In fact, it performs all the duties of an overhead traveller.

AS SUPPLIED TO THE ADMIRALTY, WAR OFFICE,
COLONIES, AND FOREIGN GOVERNMENTS.

THE Cupola.
Evans's Rapid.

Foundries Completely Furnished.

EVANS'S NEW CUPOLETTE
For Emergency Work.



James Evans & Co.,
Britannia Works,
Blackfriars,
MANCHESTER.

Telegrams: "LADLES, MANCHESTER."

Deaths.

MR. R. ISAAC, owner of the Union Ironworks, Portmadoc, died recently, aged 61 years.

THE death took place recently of Mr. J. Morris, owner of the Wyre Street Foundry, Padiham, aged 77 years.

MR. J. HIBBARD, eldest son of Mr. John Hibbard, of Messrs. T. Staniforth & Company, edge-tool makers, Sheffield, died recently, aged 37.

MR. W. M. STILL, of W. M. Still & Sons, Limited, metal workers, Hatton Garden, and Deansgate, Manchester, died recently, at the age of 57 years.

MR. W. CRAMPTON, one of the founders of the business of Crampton Brothers, engineers and vice-makers, of Sheffield, died recently at the age of 64 years.

THE death is announced of Mr. R. Brecknell, a departmental manager at the Parkgate Iron and Steel Company's Works at Rotherham, at the age of 88 years.

THE death is announced of Mr. J. Summerhill, of Messrs. James Summerhill & Company, Beaver Iron Works, Horseley Fields, Wolverhampton, at the age of 69 years.

BELGIUM has just lost one of the old school of its ironmasters by the death of M. Victor Demerbe, who was the founder, in 1869, of the rolling mills bearing his name at Mons.

MR. FITZHERBERT WRIGHT, J.P., D.L., of the Hayes, Alfreton, died at Bournemouth last month at the age of 69 years. The deceased gentleman was a director of the Butterley Company, Limited.

MR. J. E. FRENCH, chairman of the Railway Steel Spring Company, and prominently identified with a number of other large American corporations, died recently at Cleveland, Ohio, U.S.A., aged 73 years.

THE death took place, last month, of Mr. John Gill Short, of 13, Azalea Terrace North, Sunderland, aged 40 years. Deceased was the youngest son of the late Mr. George Short, shipbuilder, of Pallion.

THE death occurred recently of Mr. J. Darby, proprietor of the business of Messrs. Perry & Brooks, wrought nail and chain manufacturers, Lye, and a director of Mobberley & Perry, Limited, firebrick manufacturers.

THE death is announced of Mr. J. H. Houldsworth, a director of the Coltness Iron Company, Limited, and of the Alquife Mines and Railway Company, Limited. For many years the deceased gentleman was chairman of the Dalmellington Iron Company, Limited.

THE death is recorded of Mr. B. Turnell, of the firm of Messrs. Turnell & Odell, engineers, of Broad Green, Wellingborough. The deceased, who was 62 years of age, was at one time employed at Messrs. Mather & Son's, where he was for many years. He started business on his own account just over twenty years ago, and in 1907 he took Mr. Odell into partnership.

GEORGE GOULD,

OLD CANAL WHARF,

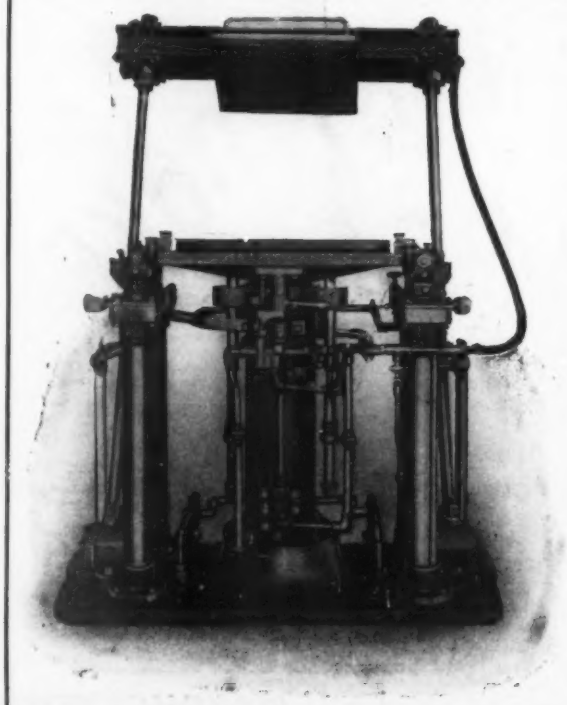
STOURBRIDGE.

FOUNDRY SAND

(MINE OWNER).

IRON AND COAL MERCHANT.

PROMPT DELIVERIES BY TRUCK OR BOAT.



Telegrams:—"Compressor, Glasgow."
Telephones:—National, 61 Maryhill, Post Office, 69 Kelvin.

John Macdonald

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Pneumatic Engineers,

WATT ST., MARYHILL, GLASGOW

"Ajax" Pneumatic Combined Jolting and Power Press Moulding Machine.

The Machine that is suitable for deep and shallow work.

The Machine that will make a complete mould in a few seconds without any hand work, forms the sand hardest about the pattern.

Inquiries and Correspondence Invited.

British Made Pneumatic Appliances for the Foundry.

SOUND

STRONG, CLOSE-GRAINED

CASTINGS

Obtained by using

"TITANIUM THERMIT"

TINS READY FOR USE. **ALL SIZES from 2 cwt. to 20 tons.**

Prices and Particulars from

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Telephone: 3749 Central.

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Works: **210a, Bow Rd., E.**

ELDERS FOUNDRY COKE

AS SUPPLIED TO THE BRITISH ADMIRALTY DOCKYARDS.

The following, selected from numerous letters, are eminent testimony as to the quality of our celebrated "A.A.A." Coppee Foundry Coke, carefully selected, and despatched in sheeted wagons.

From PECKETT & SONS, Bristol.

Bristol, October 25th, 1904.

We have been using your Selected Foundry Coke for some considerable time.
We have pleasure in stating that we are very pleased with it, as we find we get sounder and cleaner castings, more free from blowholes and other defects, than we formerly did.

From BOW, McLACHLAN & CO., LTD. (Paisley Foundry), Paisley, Glasgow.

Paisley, 12th March, 1909.

We have yours of 4th inst., and in reply have pleasure in stating that we have been using your Foundry Coke for several years for special purposes with highly satisfactory results.

Elders Collieries, Ltd., Cardiff.

PRICES OF METALS.

The following table shows the approximate latest prices and position of stocks of metals during the past two years:—

METALS.	End Dec., 1910.	End Dec., 1909.
Iron—Scotch pig warrants ton	*55/10½	*57/3
—Middlesbro' warrants ton	49/10½	51/3
—W.C. M/nos Bessemer ... ton	66 6	63 6
—Stock, Scotch ... ..tons	1,000	1,000
Copper—Chili bars, GMB ton	£56 2 6	£61 10/0
—Stock, Europe and afloat tons	†86,250	—
Tin—Engli-h ingots ... ton	£175 10/0	£152 10/0
—Straits ... ... ton	£175 10 0	£153 10/0
—Stock, London, Holland, U.S.A., and afloat ...tons	†20,846	†20,801
Lead—English pig ... ton	£13 11 3	£14 0/0
Spelter—Ord. Silesian ... ton	£24	£23 5 0
Quicksilver (75lb)... bottle	£8	£9 17 6
Antimony—Regulus ... ton	£28 0/0 £29 0/0	£80 0/0

* Settlement price. † November 30.

CASTINGS.

In the Cleveland district the following are the nominal rates current for castings:—

	£ s. d.		£ s. d.
Columns (p'ain)	6 10 0	to	6 15 0
Pipes, 1½ to 2½ in.	4 17 6	to	5 2 6
,, 3 to 4 in.	4 10 0	to	5 0 0
,, 5 to 8 in.	4 7 6	to	4 10 0
,, 10 to 16 in.	4 7 6	to	4 10 0
,, 18 to 24 in.	4 7 6	to	4 10 0
Chairs	3 10 0	to	3 12 6
Floor plates (open sand)	3 0 0	to	3 5 0

SCRAP.

The quotations for scrap, subject to market fluctuations, are as follows:—Heavy wrought (mixed), £2 10s. 0d.; light wrought, £1 7s. 6d.; heavy cast, £2 7s. 6d.; all per ton, f.o.b., London. Copper (clean), £52 10s. 0d.; brass (clean), £39 0s. 0d.; lead (usual draft), £12 5s. 0d.; zinc, £19 5s. 0d.; all per ton delivered merchant's yard.

THE late Mr. Edward Pritchard Martin, of The Hill, Abergavenny, a Past-President of the Iron and Steel Institute, and a director of Guest, Keen & Nettlefolds, Limited, left estate of the gross value of £236,249 0s. 3d., of which the net personalty has been sworn at £213,218 2s. 2d.

MR. WM. CLARK has been the recipient of a presentation from the members of the Scottish Steel Makers' Association, on the occasion of his leaving Scotland to take up the position of general manager at the works of Vickers, Sons & Maxim, Limited, Sheffield. Up to the time of his appointment to the position at Sheffield, Mr. Clark was chairman of the Association.

Personal.

THE late Mr. Ralph White, of the Novelty Iron Works, Northwich, left estate valued at £2,379 gross.

THE King has been pleased to confer the Order of Merit on Sir William Crookes, F.R.S., the well-known scientist.

MR. W. MEDCALF has been appointed manager to the Burnley Iron Works Company, Limited, King Street, Burnley.

THE late Mr. Andrew Cook, of the firm of Wm. Cook & Sons (Sheffield), Limited, of Sheffield, left personal estate valued at £14,488.

MR. A. T. BLACKALL, a G.W.R. signal engineer, has been elected the first President of the recently-formed Institution of Signal Engineers.

THE late Mr. F. W. Wells, at one time assistant manager of the steel works of Vickers, Sons & Maxim, Limited, Sheffield, left estate valued at £3,583 gross.

MR. F. DUDLEY DOCKER, of Birmingham, will preside at the sixty-eighth anniversary festival of the Royal Metal Trades' Pension Society to be held in London in the month of June.

THE gross value of the estate of the late Mr. R. Robinson, Crabtree Lane, Pitamoor, Sheffield, manager for Brown Bayley's Steel Works, Limited, is £16,698, of which £16,619 is net personalty.

THE late Mr. James Riley, of Bilton Lodge, Kent Avenue, Halifax, first President of the West of Scotland Iron and Steel Institute, left estate valued at £19,040 gross, with net personalty nil.

MR. H. N. SPORBORG, chief engineer, and Mr. W. C. Lusk, manager of the export department of the British Thomson-Houston Company, Limited, have been elected members of the board of directors.

THE late Mr. J. E. Marley, of the firm of Sproat, Marley, & Company, Limited, engineers and iron and steel founders, Hebburn, left estate valued at £7,983 8s. 5d. gross, with £6,715 16s. net personalty.

MR. JOHN FRITZ, of Bethlehem, Pa., U.S.A., was recently the guest of honour at a dinner given by the Manufacturers' Club of Philadelphia, as an expression of regard for him. Mr. Fritz, who is 88 years of age, was the recipient of the Elliott Cresson medal.

SIR ROBERT HADFIELD has been presented with the Elliott Cresson Gold Medal by the Franklin Institute (U.S.A.), for work "in the advancement of our knowledge of metallurgical science." This is the second recognition Sir Robert has received from the same source, the John Scott Legacy Medal and Premium having been awarded him in 1891.

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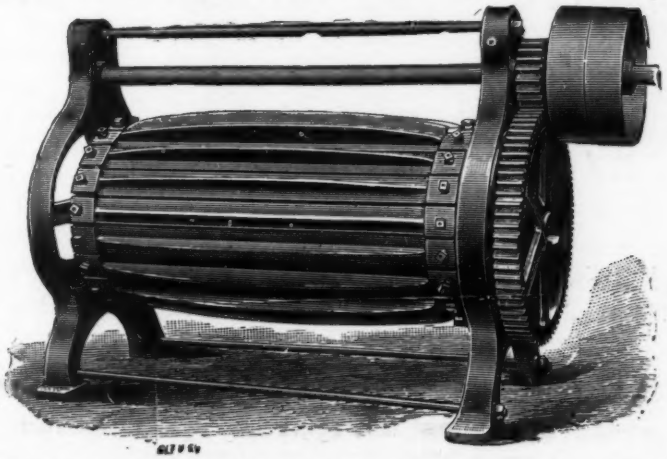

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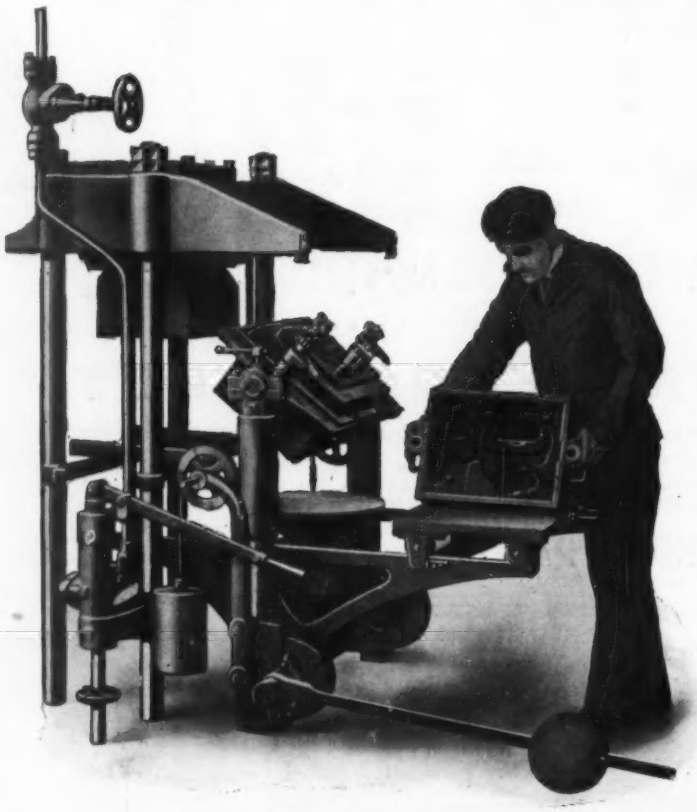

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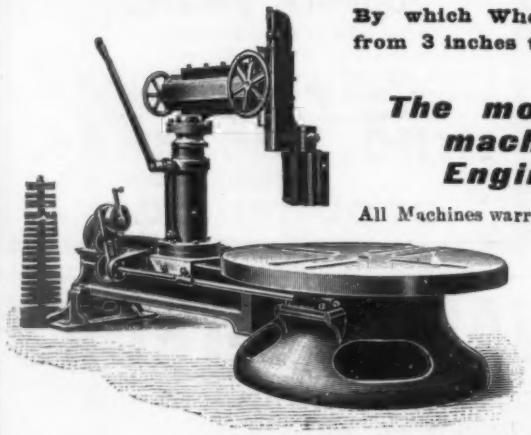

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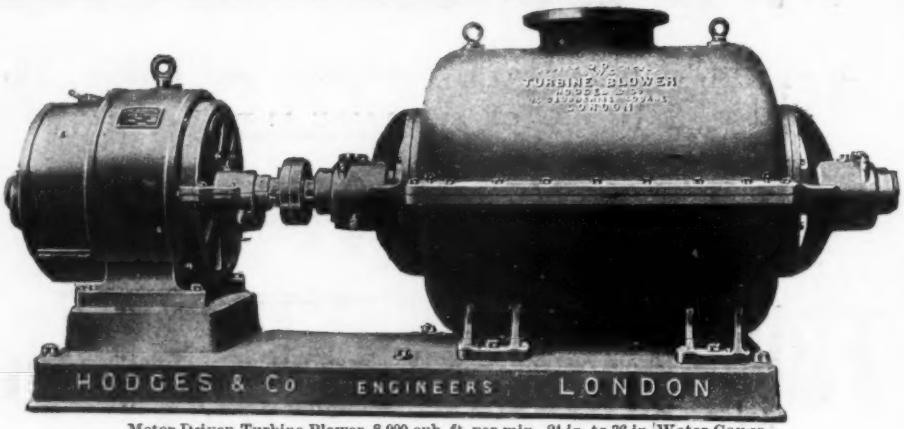

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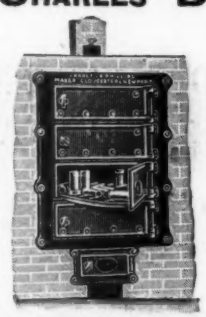

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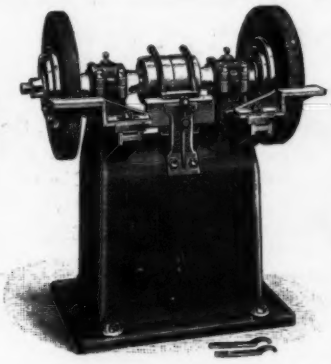

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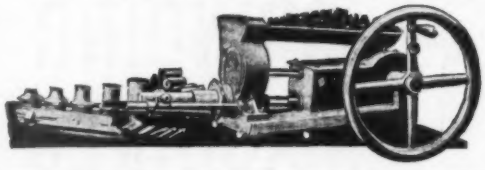

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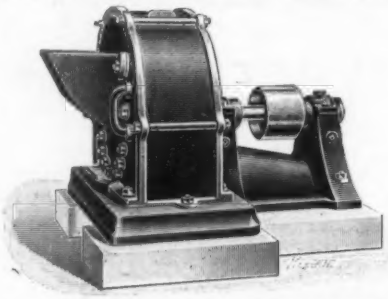

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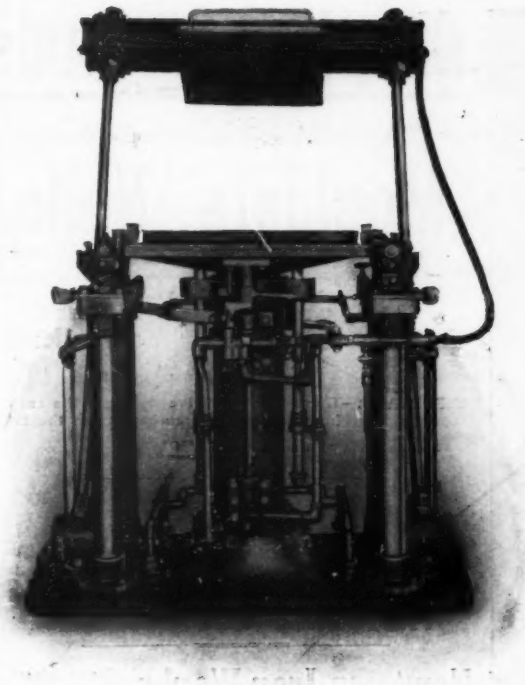

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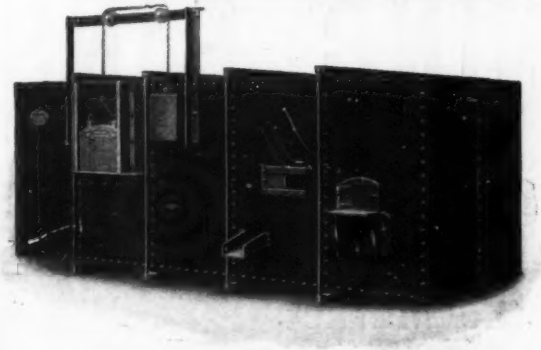

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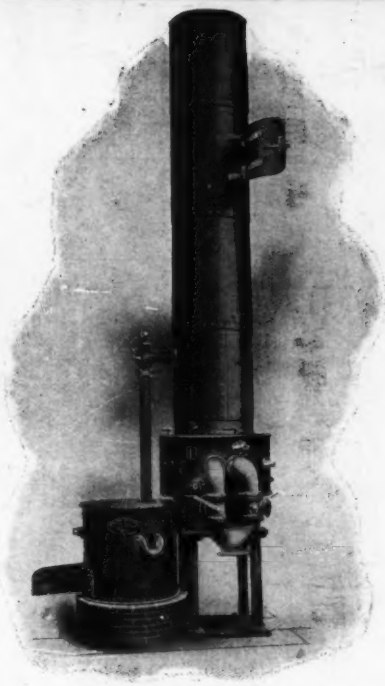

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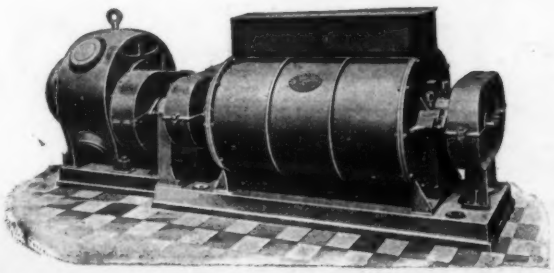

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